FEEDERHOLE DIE

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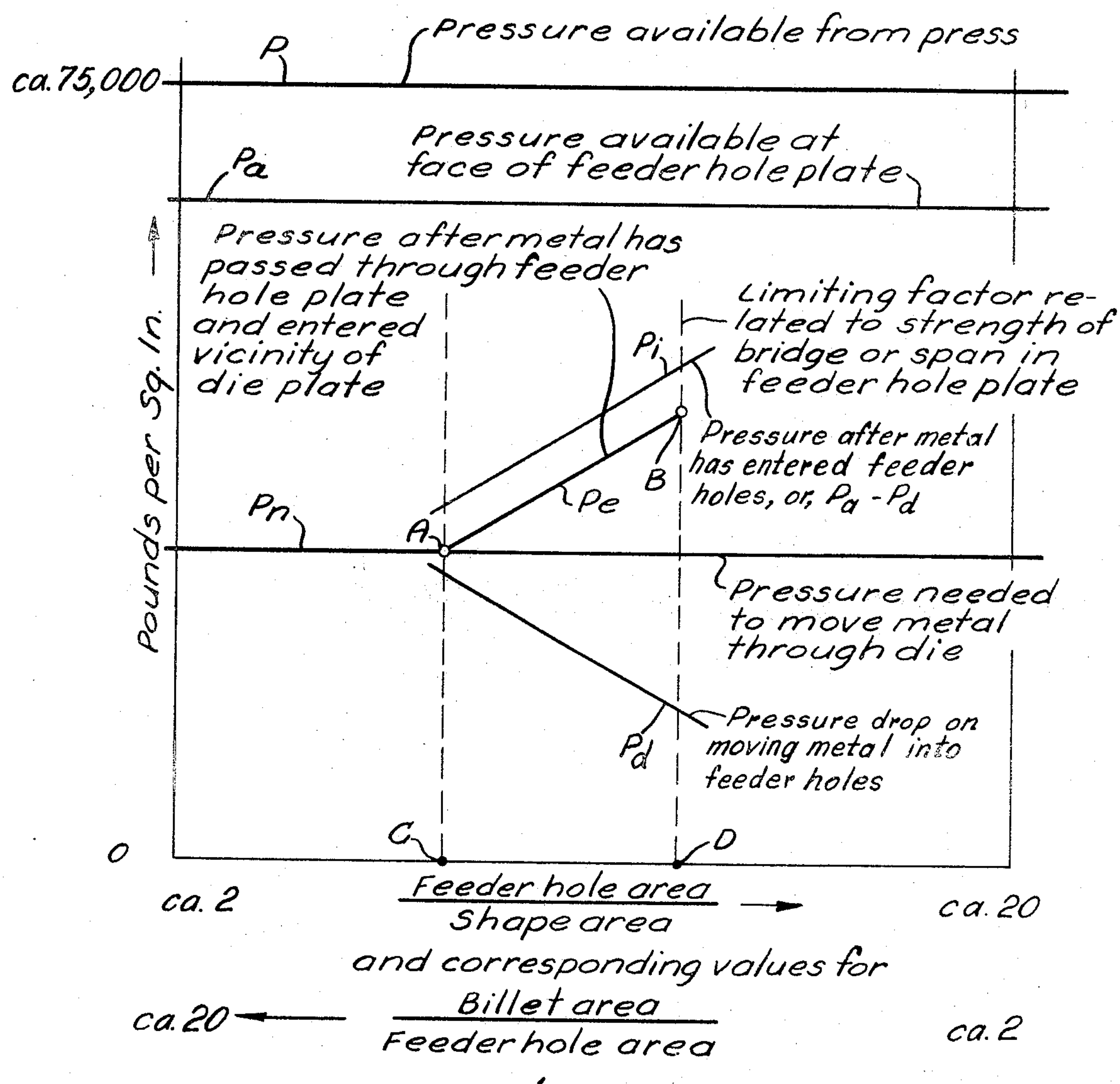

Fig. 1

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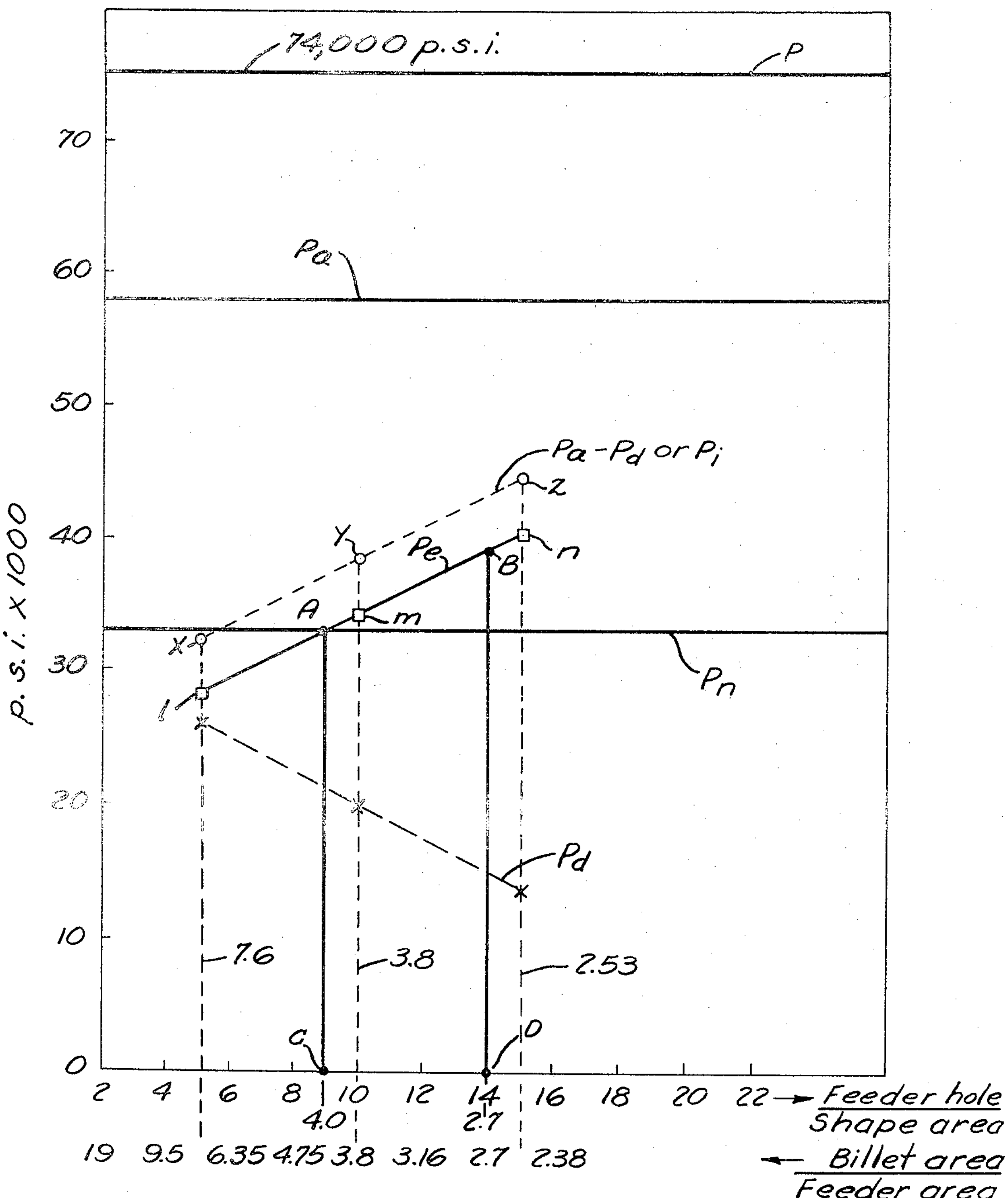

Fig. 2

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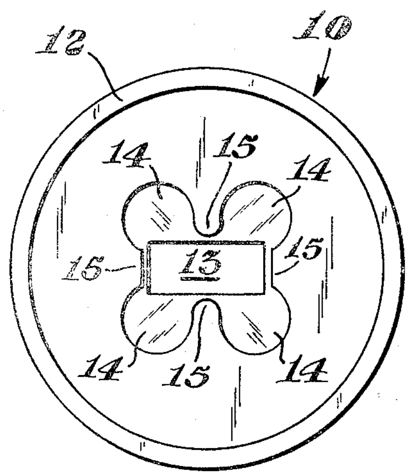

Fig. 3

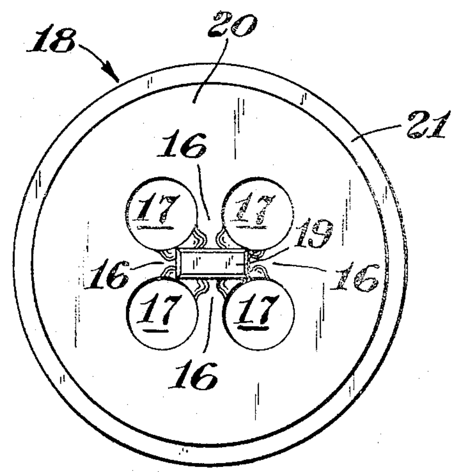

Fig. 4

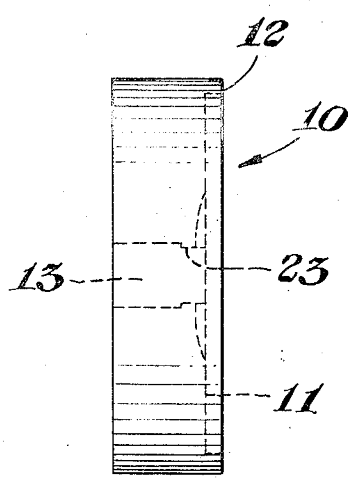

Fig. 5

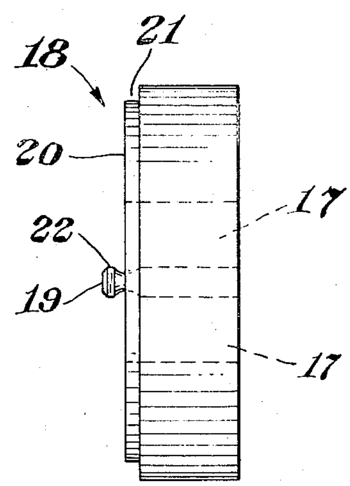

Fig. 6

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3,520,168
FEEDERHOLE DIE
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Int. Cl. B21c *25/04*
U.S. Cl. 72—269 7 Claims

ABSTRACT OF THE DISCLOSURE

A greatly improved porthole die consisting of a feederhole plate and a complementary die plate, intended for extrusion of a pre-selected alloy provided in the form of a billet of pre-selected cross-sectional area to be extruded into a shape of pre-selected cross-sectional area is provided if the ratio of the pre-selected cross-sectional area of the billet to the total summed-up cross-sectional areas of all the feederholes is a value in the range along the line C–D of the graph in FIG. 1 of the drawing, provided further, that the feederhole plate has a thickness not substantially greater than needed to withstand extrusion pressures that are sufficient to cause the pre-selected alloy to move through and exit from the porthole die. The unusually thin feederhole plates used according to the invention provide for the extrusion of substantially greater amounts of metal per unit time at substantially lower temperatures and the die life is substantially greater than normally experienced heretofore.

The invention relates to an improped feederhole die for the extrusion of light metals into hollow shapes including both single hole and multi-hole hollow shapes. Such dies are also known as porthole dies.

The present dies are intended especially for the extrusion of magnesium and aluminum and alloys having one of the same for the basis metal to the extent of at least 70 percent by weight of the alloy.

Such feederhole dies are generally made of a high strength steel such as a tool steel having substantial tensile yield strength and compression yield strength at temperatures up to 800° F., i.e., at about maximum temperatures at which magnesium and aluminum and their alloys are die extruded. An example of a suitable steel so employed contains about 5 percent by weight of chromium and has an A.I.S.I.–S.A.E. designation of H11 or H12.

A feederhole die assembly consists of, apart from the rest of the extrusion press, a feederhole plate and a die plate. Each plate is a substantially circular disk having openings formed therethrough. The openings in the feederhole plate are referred to as feeder holes or port holes. The opening or openings in the die plate are each referred to as a die orifice. On the side of the feederhole plate away from the billet and facing the die plate are integrally formed one or more mandrels which are designed to be positioned at least part way into one or more die orifices. The die assembly is held in place and supported by additional structure, ordinarily readily movable in the commercial installation and adapted to releasably hold the die assembly against the container. Normally, the die plate and the feederhole plate have diameters substantially the same as, or slightly larger than, the diameter of the container, depending upon the particular press design.

Extrusion with such die assemblies is carried out on an extrusion press having hydraulic piston means for applying large amounts of total push, e.g. upwards of 5000 tons and ranging up to about 14,000 tons. The pressure from the piston is transmitted by a ram having a dummy

block fitted on the outer end thereof. The dummy block is adapted to fit into the cylindrical container of the press. The container is of a preselected size adapted to receive cylindrical billets of the metal to be extruded. The dummy block fits the perimeter of the cross-section of the container closely enough that the billet does not extrude backward around the dummy block during extrusion of the billet. Pressure from the press transmitted to the billet by the ram causes the billet to slide within the container until it is forced up against the porthole die assembly, which extends across an end of the container. As pressure from the press is maintained, and perhaps also increased, the metal flows plastically through the feeder holes, around the mandrel(s) and through the die orifice(s).

In sliding the billet through the container, a substantial amount of the nominal capacity of the press is consumed in frictional engagement of the billet with the walls of the container. The remaining pressure is computed according to the following formula:

$$P_a = P\left(e^{4\mu \frac{L}{D}}\right)^{-1}$$

wherein:

P_a=the reduced pressure available at the billet face of the feederhole plate in pounds per square inch (p.s.i.).

P=the capacity of the press in p.s.i.

e=the base of the natural logarithm.

μ=the coefficient of friction between the metal being extruded and steel.

L=length of the billet, in inches.

D=diameter of the container, in inches.

This reduced pressure, P_a, is that which is available to force the metal into and through the feederhole plate, around the mandrel(s), and through the die orifice(s).

If the total feederhole area is relatively small in comparison to the cross-sectional area of the billet, it would be expected that a substantial amount of effort would be needed to force the metal through the feederhole plate. If the feeder holes, collectively, provide a very large area, the metal will flow through the plate relatively easily. However, with large total feeder hole area, bridges between feeder holes must necessarily be limited in width or have a long span and are thereby relatively weak. Moreover, such bridges provide less suport for mandrels attached thereto. In order to compensate for this, it was thought necessary, heretofore, to employ a feederhole plate of substantial thickness and moreover to limit the feeder hole area somewhat in order to retain bridges of substantial width. However, thickening of the feederhole plate and widening of the bridges each increase friction between the plate and the metal flowing therethrough. Such increased friction makes larger hydraulic pressure capacity of the press necessary, imposes larger tensile yield strength requirements on the die metal, necessitates increased plastic flow or deformation of the metal being extruded around the die parts and increases both die wear and the probability of other damage to the die.

Solid shapes are obtained on extruding metal through an unobstructed die opening in a die plate. Hollow shapes are commonly made by extruding metal through a feederhole plate, around a mandrel and through a die opening, the mandrel being supported in the die opening by the feederhole plate so as to partially obstruct the opening. The feederhole plate of the prior art is provided with several feeder holes through which the metal flows from a billet in the container of the extrusion press to the die opening, whence the name, feederhole die. Multi-hole hollow shapes are made in the same manner except that a plurality of mandrels is employed, one for each longitudinal cavity or hole in the extrusion. A typical single hole extrusion is a cylindrical tube. A typical multi-hole extrusion made by means of a feederhole die is a hollow panel for vehicle floors. Such a panel has opposed planar surfaces, each perhaps 0.2 inch thick, supported and spaced about 2 inches apart by a series of integral connecting webbing members, each having about the same thickness as the planar surfaces. A typical panel might be 24 inches wide with about 13 webbing members so that the panel has, in effect, 12 holes running the full length thereof. The metal defining each hole is formed around a mandrel. During the extrusion operation, the entire substantially rectangular die opening has 12 mandrels positioned therein in a substantially straight line array. Other shapes may be made as desired.

Feederhole dies of the type described hereinbefore have been used for many years for extruding such hollow shapes, and especially the single hole hollow shapes. However, a multi-hole shape such as the panel described above presents new problems. When prior art methods for designing feederhole dies are applied to multi-mandrel dies defective extrusions are produced. In addition, as set forth in the discussion of the art processes and dies, difficulties have been encountered with cracking and breaking of mandrels or mandrel support structures and with excessive wear of the die parts, including those used in making single hole hollow shapes.

It is therefore a principal object of the present invention to provide an improved feederhole die for the extrusion of both single hole and multi-hole hollow shapes which is not subject to excessive wear and which is substantially free of deforming and cracking of mandrels and mandrel supports.

It is an additional object of the invention to provide an improved feederhole die for the extrusion of hollow shapes which does not require an unduly large press capacity for the proper extrusion of hollow shapes.

Another object of the invention is to reduce wastage of the nose section of each push and to provide for better welds between the streams of metal flowing through the feeder holes and rejoining to form the shape or final extruded article.

These and other objects and advantages of the present invention will be more apparent to those skilled in the art upon becoming familiar with the following description and the appended drawings in which there is shown in FIG. 1, by way of a graph, the desired relationship between pressures available and needed for extrusion of the metal in relationship to the ratio between the cross-sectional area of the billet and the cross-sectional area of the feeder holes. The graph in FIG. 2 illustrates numerical values for a specific embodiment of the present die.

An example of each of the die plate and feederhole plate, which together exemplify a feederhole die, are shown in FIGS. 3–6 in which like reference numerals refer to like parts. FIG. 3 is a view in front elevation of such a die plate as viewed from the feederhole plate side. FIG. 4 is a view in front elevation of a unitary feederhole plate complementary to the die plate of FIG. 3, viewed from the die plate side. The die plate is viewed in side elevation in FIG. 5, while the feederhole plate is shown in side elevation in FIG. 6.

Referring now to FIGS. 3 and 4, the die plate indicated generally by the numeral **10** is seen to have a generally planar surface **11** surrounded by a peripheral flange portion **12**. A centrally located die orifice **13** extends clear through the die plate. Bevelled out areas **14** slope upwardly from the die orifice to the plane of the plate surface **11**. The bevelled out areas are in part defined and separated by unbevelled areas **15** which are known in the art as pads. The pads **15** provide essential support to correspondingly located bridges **16** of metal remaining between feeder holes **17** in the feederhole plate indicated generally by the numeral **18**. The bridges **16** provide support for the integrally formed structure holding the mandrel **19** upwardly from the plane of the planar surface **20**. A peripheral recess **21** of the feederhole plate complementary to flange **12** of the die plate provides indexing means for precise alignment of the plates when in juxtaposed and contiguous relation while in use in an extrusion press.

In FIGS. 5 and 6, each plate, as viewed, is turned so that the direction of metal movement through such plate during extrusion is from right to left. When such plates are juxtaposed and placed in use, surface **20** of the feederhole plate **18** contacts surface **11** of the die plate **10**, the flange **12** mates with the recess **21**, and the mandrel **19** extends into the die orifice **13** so that the bearing land **22** of the mandrel is substantially aligned with the die land **23**.

The design of the improved feeder hole die of the invention is based on the discovery that upon maintaining each of (1) the ratio of the cross-sectional area of the feederholes to the cross-sectional area of the die orifice, and (2) the ratio of the cross-sectional area of the billet to the cross sectional area of the feederholes in the range of values between points C and D on the X-axis of the graph of FIG. 1 of the drawing, and, in addition, upon limiting the thickness of the feederhole plate to that which does not provide substantially more shear strength and resistance to bending than is required to resist the pressures in a range corresponding to the points A and B on the graph of FIG. 1 of the drawing, magnesium or aluminum or the alloy of either are easily extruded into a hollow shape with a minimal amount of pressure from the press and substantially without either deforming or cracking any mandrel employed or the support structure therefor, including the feederhole plate, during an unusually long service period which is substantially greater than the service life of prior dies.

In accordance with the present invention, therefore, it has now been found that surprising material benefits are had upon decreasing the thickness of the feederhole plate and on maintaining a proper relationship between billet area, feederhole area and the area of the die orifice or orifices. It has further been found possible to define those relationships in the following manner:

The amount of pressure drop, P_d, in moving the metal into, but not through a feederhole plate having a given feederhole area is calculated as follows:

$$P_d = K \times 4 \times TYS \times \ln\left(\frac{\text{Billet area}}{\text{Feederhole area}}\right)$$

wherein:

$$K = \frac{\text{bearing land area of feeder hole}}{\text{bearing land area of equivalent round holes}} \times \ln\left\{\frac{\text{Circumference of feeder hole}}{\text{circumference of equivalent round hole}}\right\}$$

wherein the first fraction is unity for practical purposes, and n equals the number of feeder holes, while TYS= tensile yield strength of the metal to be extruded.

On selecting a light metal alloy, feederhole plate thickness, billet size, press capacity, and cross-sectional area for the shape to be extruded, and on further selecting a series of prospective feederhole areas, there can be calculated a series of values for P_d, e.g., three values designated x, y and z, respectively, using the above formula. Upon plotting values x, y and z as on the graph of FIG. 2, and connecting them with a line, there is obtained the line or curve, P_i, as found in both of FIGS. 1 and 2. Also plotted on the graph of each of FIG. 1 and FIG. 2 as horizontal lines are P, nominal press capacity, and P_a, the pressure available at the billet side of the feederhole plate.

P_i represents the pressure usable to move the metal through and out of the feeder holes. The pressure remaining after this operation is the pressure, P_e, available to effectively move the metal through the die orifice. P_e values are computed from P_i values according to the following equation:

$$P_e=P_i\left(e^{\frac{2(a+b)L\mu}{a\times b}}\right)^{-1}$$

wherein:
e=base of the natural logarithm.
a=height of feederhole, in inches.
b=width of feederhole, in inches.
$a=b$ if the feederhole is square. If feederholes are round then formula reads:

$$P_e=P_i(e^{4L/D\mu})^{-1}$$

If the shape is other than round, the formula is to be modified in accordance with mathematical principles.

μ=coefficient of friction between the alloy and the die metal.
L=thickness, in inches, of feederhole plate selected to have the required capacity for shear and bending stresses expected.

Using the said three values of P_i, three values of P_e may be calculated, and designated l, m and n. On plotting these values as on the graph of FIG. 2, and connecting the points with a line, there is obtained line P_e, showing effective pressures available at the die orifice.

It is then necessary to calculate how much pressure, P_n, is required just to move the metal through the die orifice and to compare P_e values thereto. The pressure so required is related to the ratio of the total area, from which the metal is actually fed into the die orifice, to the cross-sectional area of the shape being extruded. The area from which the metal is fed into the die is sometimes referred to as the welding chamber area. It is that area in which the streams of metal, separately formed by the bridges between the feeder holes, join to flow into a single shape. This area tends to change very little with proper design variations in cross-sectional area of the feeder hole openings for a given shape being extruded from a given size billet. It is believed that such changes are too small to be taken into account in making calculations for practical purposes, though a more rigorous treatment would require taking such small changes in area into account. With changes in general geometry of the shape, the arrangement of the feederholes and their configurations will necessarily affect the welding chamber area, and these changes would more significantly affect the present calculation.

The pressure required is further related to the tensile yield strength of the alloy. These relationships are shown in the following equation:

$$P_n=K\times 4\times TYS\times \ln.\left(\frac{\text{Welding chamber area}}{\text{shape area}}\right)$$

wherein:
P_n=pressure needed for extrusion, in p.s.i.
TYS=tensile yield strength of the alloy at the temperature of extrusion, in p.s.i.
K=factor indicating how much more difficult a shape is to extrude than a round bar of equal cross-section. K is computed as follows:

$$K=\frac{\text{Bearing length of the die orifice}}{\text{Bearing length of a round bar of equivalent section}}\times\frac{\text{Perimeter of die orifice plus perimeter of all mandrels}}{\text{Circumference of round bar of equivalent cross-section to the extruded shape}}$$

Upon plotting the value of P_n as a straight horizontal line along with the various values already computed and plotted in the manner shown in the graph of FIG. 2, there is obtained a bilinear graph in which there appears an intersection of line P_e with the line P_n at the point designated A on the graph. Under the conditions corresponding to each of the variables which determine point A, the metal will barely move through the die orifice. A vertical line passing through point A and intercepting the X axis at point C indicates the maximum value for the ratio of billet area to feederhole area which may be employed and still obtain the extrusion of some metal according to the invention.

A second vertical line as shown in the graph, in each of FIG. 1 and FIG. 2 in the drawing is based on a limiting factor related to both the shear and bending stresses to which the tool steel forming the bridges in the feederhole plate may be subjected, especially in certain critical areas, e.g., where the bridges are integrally joined to the mandrel(s). This factor limits the extent to which the bridges of the feederhole plate may be narrowed while still retaining sufficient strength to hold the plate together. The point at which the limiting factor line crosses the line P_e is designated B on the graph. The intercept of this line with the X axis as point D indicates the lower limit for the ratio of the billet area to feederhole area which may be employed according to the invention, in other words, maximum feeder hole area. Any vertical line drawn from the line P_e between points A and B, to the X axis indicates both an acceptable ratio for billet area to feeder hole area, and an acceptable ratio for feeder hole area to shape area, according to the invention, for the alloy, billet size, shape size, etc., selected. Any die so designed provides for ready flow of metal through the die, requires minimal press capacity, provides for longer service life of the mandrels and mandrel supports, and otherwise fully meets the objectives of the invention.

In general, the thickness of feederhole plate which is suitable for the present die is that which is not substantially greater than needed to resist the extrusion condition pressure, from the billet side, on bridges in the plate having dimensions nominally expected for the type and size of shape being extruded. If the plate is made substantially thicker, greater pressure must be provided by the hydraulic system of the press in order to overcome increased frictional losses and transmit sufficient pressure to the die plate area to cause extrusion. But, increased pressure from the hydraulic press places greater stress on the feederhole plate increasing the strength requirements and requiring still stronger, thicker bridges and a thicker feederhole plate.

The selection of the proper thickness of the feederhole plate according to this invention is based on both (1) the selection of feederhole area, giving rise to the proper billet area to feederhole area ratio, and (2) the feederhole configuration, alignment and spacing described and claimed in my copending application of even date herewith. Feederhole configuration, alignment and spacing, according to said application, are properly selected when the metal flows fluently through the die assembly in a straight line, as much as possible, and with a minimal amount of metal remaining under the bridges at the end of each push, i.e., at the conclusion of extruding each billet. Further, the metal flowing next to a bridge must not be made to flow away from straight line passage through both the feederholes and die orifice a distance greater than corresponds to about 0.2 times and preferably 0.1 times the axial thickness of the feederhole plate, and especially of the bridges. This distance from straight line flow is also the distance the stream of metal must move to rejoin the stream of metal flowing through the next adjacent feederhole. The distance of transverse flow is a very important consideration. This same principle is also to be applied to any other transverse flow of the metal with respect to the long axis of the shape, e.g., in the case of multi-hole hollow shapes with perpendicular ribs or webbing members, or with diagonal webbing members as in a truss-cored section. Persons skilled in the art will readily perceive that the transverse width of the shape will not be limited by the above ratios of 0.1 to 0.2, since the thicker feederhole plate which will be necessary can quite properly be employed according to the present invention.

Upon selecting an appropriate feederhole area, and further, upon selecting proper feeder hole spacing and alignment about the mandrel(s) to meet these conditions, the number of feederholes and their spacing about the perimeter of the mandrel(s) becomes relatively fixed. The spacing determines bridge widths in a practical way. With total area and spacing selected, the lengths or heights of feeder holes become fixed. This determines the bridge spans. Bridge widths and spans having been thus inherently selected, the determination of the minimum bridge thickness, and thus plate thickness, follows from a straightforward consideration of pressure on the bridge and the strength properties of the tool steel in the die at normal extrusion temperatures.

Using the design methods of the invention, feederhole plate thicknesses selected are not more than about 40 to 60 percent as great as for the feederhole plates of the prior art.

Among the advantages of the present die design is the provision for narrow bridges which permit fluent flow of the metal through aligned feeder holes and die orifices as more fully described and claimed in my co-pending application of even date herewith. The close spaced feeder holes provide sufficient support for the mandrels utilizing bridges having a width as narrow as ¼ to ½ of the diameter of the adjacent feeder holes. The present design also provides for feeder hole diameters, or lengths, if oval, of up to 3 times the length of webbing members in a multi-hole extrusion.

As an example of the die design according to the present invention, the following computation is made for the extrusion of 6061 aluminum alloy at a temperature of 800° F., the metal being provided in the form of a billet 22 inches in diameter and 65 inches long, the feederhole plate being 4 inches thick and the press capacity being 14,000 tons. The metal is to be extruded into a shape having a cross-sectional area of 10 square inches. In FIG. 2, pressures are plotted in thousands of pounds per square inch vs. the ratio of feeder hole area to shape area. Ratios of the billet area to the feeder hole area corresponding to the ratios of feeder hole area to shape area are also shown along the X axis.

The minimum pressure required to barely move metal through the die orifice is computed as follows:

$$P_n = K \times 4 \times TYS \times \ln\left(\frac{\text{Welding chamber area}}{\text{Shape area}}\right)$$

Using values for the respective bearing lengths, which determine K, of 0.4 and 0.8, using a perimeter value of 124 inches for a preselected shape and computing that the circumference of an equivalent round bar is equal to 11.3 inches, K is in turn, computed to have a value of 5.5. The tensile yield strength of 6061 alloy at 800° F. is approximately 800 p.s.i. A welding chamber area of 64 square inches has been found by experience to be typically suitable. Using indicated values, P_n is calculated to be 32,600 p.s.i. This value corresponds to the line P_n of the graph in FIG. 2.

The necessary and desirable conditions for exceeding P_n and thereby ascertaining satisfactory die assembly design for which metal will move through the die may then be determined.

The press capacity is computed to be:

$$P = \frac{14{,}000 \text{ tons} \times 2000 \text{ pounds}}{380 \text{ square inches}}$$

or 74,000 p.s.i. and is plotted in FIG. 2 as a horizontal line designated P. The pressure at the billet side of the feederhole plate, P_a, is computed as follows:

$$P_a = 74{,}000 \text{ p.s.i. } (R^{4\mu L/D})^{-1}$$

From experience, the coefficient of fraction, μ, between 6061 alloy and the steel of the container has been found to be about 0.02. Using 65 inches for the length of the billet and 22 inches for the diameter of the container, P_a, is calculated to be 58,000 p.s.i. This value appears on the graph in FIG. 2 as line P_a.

It is now possible to compute the pressure drop, P_d, involved in moving the metal into, but not through the feeder holes for three different feeder hole sizes arbitrarily selected and amounting to a total area of 50 square inches, 100 square inches and 150 square inches, respectively. The pressure drop is computed according to the following expression:

$$P_d = K \times 4 \times TYS \times \ln\left(\frac{\text{Billet area}}{\text{Feeder hole area}}\right)$$

Computing K in about the same manner as indicated above, the ratio of the bearing lengths can be taken as unity since no bearing land is involved. Computing the total circumference of feeder holes over the circumference of equivalent round holes, yields values for K, respectively, of 4, 4.8 and 4.4 for the three respective feeder hole areas. Using 800 p.s.i. for the expression TYS and inserting 380 square inches for billet area, and 50, 100 and 150 square inches, respectively, for the feeder hole area in the expression, there are obtained P_d values, respectively, of 25,200 p.s.i., 20,000 p.s.i., and 13,000 p.s.i. On plotting these values and connecting them with a line, there is obtained the line P_d of FIG. 2. On subtracting the P_d values from P_a, there are obtained the pressures remaining, P_i, after the metal has moved into the feederhole plate. The resulting values for P_i are, respectively, 32,800 p.s.i., 38,000 p.s.i. and 44,900 p.s.i. On plotting these P_i values, on the graph in FIG. 2, against the corresponding ratios of billet area to feederhole area, and on connecting the three points with a line there is obtained the curve designated P_i.

A further pressure decrease takes place as the metal now fills and flows through the feederholes resulting in pressure P_e, the pressure effectively available to force the metal through the die orifice. This pressure is computed as follows:

$$P_e = P_i \left(e^{\frac{2(a+b)L\mu}{a \times b}}\right)^{-1}$$

Inserting the values for a, 1.75, 1.9 and 2.2, respectively, and for b, 2.4, 4.4 and 5.7, respectively, using 4 inches as L, the thickness of the plate, using the value 0.02 for μ, and employing the values just listed for P_i, P_e values of 28,000, 33,500 and 40,300 are obtained.

On plotting such P_e values against corresponding billet area to feederhole area ratios in the graph of FIG. 2, and connecting the joints obtained with a straight line, the line designated P_e is obtained. The line P_e, as shown, intersects line P_n at point A. At the point marked A, a vertical line drawn through to the X axis and intersecting the latter indicates that using a maximum ratio of billet area to feederhole area of about 4 permits some extrusion of metal under these conditions.

The vertical line intersecting P_n at point B and representing the limiting factor for the die metal involved intersects the X axis at a value of about 2.7 indicating the minimum ratio which may be employed at the reasonable safe limits of strength of the die metal. Preferably, P_e is about 10 percent above that barely sufficient for extrusion and 6061 alloy is best extruded using a billet area to feederhole area ratio in the range of about 2.7 to about 3.8, and most preferably at a ratio of about 3.3.

While it is possible to make shapes, of the types disclosed, in other ways, the present method provides for making such shapes with a surprising improvement in efficiency of the total operation. Many bad or adverse features are reduced to a seemingly absolute minimum, such as, wastage of the nose section of the metal pushed from each new billet, bad welds or seams, and large pressure requirements on the press capacity because of frictional losses. On the other hand, provision is made for bringing out the best of the desirable factors commensurate with an economically feasible and useful life of a die made from presently available steels.

The improved die of the invention having been thus fully described, various modifications thereof are at once apparent to those skilled in the art and the scope of the invention is to be considered limited only by the breadth of the claims hereafter appended.

I claim:

1. In a porthole die, for extrusion from an extrusion press of a preselected extrudable alloy provided in the form of a billet of preselected cross-sectional area to form a shape of preselected cross-sectional area, which die comprises a unitary feederhole plate and a complementary die plate; said die plate having at least one die orifice formed therethrough; said feederhole plate being formed of a pre-selected die metal and having a plurality of feeder holes formed therethrough and at least one mandrel integrally formed therewith and supported thereby, said at least one mandrel extending into, respectively, the at least one die orifice when the die plate and feederhole plate are assembled together in juxtaposed operative relation; and said feederholes being closely aligned with each die orifice fed thereby; the improvement which comprises:

that the total summed up cross-sectional areas of all the feeder holes, the billet diameter, the capacity of the press, and the nature of the pre-selected alloy are such, collectively, that the pressure transmitted by the said alloy upon entering the feeder holes is a value along P_i of the graph of FIG. 1 of the drawings, said pressure P_i reflecting the pressure drop P_d, from P_a, the pressure available at the face of the feederhole plate on moving the alloy just into the feeder holes, where P_a is computed from press capacity P according to the equation:

$$P_a=P\left(e^{4\mu\frac{L}{D}}\right)^{-1}$$

wherein P=capacity of press in pounds per square inch

e=base of the natural logarithm

μ=coefficient of friction between said alloy and the die metal

L=length of billet in inches

D=diameter of billet in inches

and P_d is computed according to the equation:

$$P_d=K\times 4\times TYS\times \ln\left(\frac{\text{Billet area}}{\text{Feederhole area}}\right)$$

wherein TYS=tensile yield strength of said alloy in pounds per square inch and

$$K=\frac{\text{bearing land area of feeder hole}}{\text{bearing land area of equivalent round holes}}\times n\left(\frac{\text{circumference of feeder hole}}{\text{circumference of equivalent round holes}}\right)$$

wherein n=number of feeder holes

that the said cross-sectional areas and the thickness of the feederhole plate taken together are such that said pressure P_i is reduced to a pressure along the line P_e of said graph upon moving the alloy through the feederhole plate and to the vicinity of the die plate, P_e being computed from P_i according to the equation:

$$P_e=P_i\left(e^{\frac{2(a+b)L\mu}{a\times b}}\right)^{-1}$$

wherein

e=base of the natural logarithm

a=hegiht of feederhole in inches

b=width of feederhole in inches

μ=coefficient of friction between said alloy and the die metal

L=thickness, in inches, of feederhole plate

corresponding values of P, P_a, P_d, P_i and P_e lying on a common line normal to the X-axis of said graph;

that the cross-sectional area and complexity of the shape and the properties of said alloy are such as to require a minimum pressure to move the said alloy through the die orifice at the extrusion temperature of the alloy, such pressure minimum having a value P_n on said graph and being computed according to the equation:

$$P_n=K\times 4\times TYS\times \ln\left(\frac{\text{Welding chamber area}}{\text{Shape area}}\right)$$

wherein TYS=tensile yield strength of the alloy at the temperature of extrusion in pounds per square inch

$$K=\frac{\text{Bearing length of the die orifice}}{\text{Bearing length of a round bar of equivalent section}}\times\frac{\text{Perimeter of die orifice plus perimeter of all mandrels}}{\text{Circumference of round bar of equivalent cross-section to the extruded shape}}$$

that the ratio of the total summed up cross-sectional areas of all the feeder holes to the cross-sectional area of the shape and the corresponding ratio of the cross-sectional area of the billet to the total summed up cross-sectional areas of all the feeder holes both fall between points C and D on the X axis of said graph, said point C arising from a line drawn vertically from the intersection of line P_e with line P_n downwardly normal to the X axis of the said graph, and point D arising from a line drawn vertically at B from the intersection of line P_e with a limiting factor related to both of the reduced strength of the feeder hole plate with larger feeder holes and the extrusion pressures involved, downwardly normal to the X axis of said graph, thereby providing for sufficient pressure at the die plate for extrusion to take place without weakening the feeder hole plate sufficiently for it to break readily;

and that the feeder hole plate has a thickness not substantially greater than needed to withstand, without breaking, extrusion pressures exerted, on the billet side, suffiicent to cause the pre-selected alloy to move through and exit from the porthole die.

2. The porthole die as in claim 1, in which the feederholes are defined, in part, by bridges between adjacent feederholes, and a stream of metal forced through the die and along a line at an edge of one of said bridges does not move transversely to rejoin the stream of metal flowing through the next adjacent feederhole a distance greater than about 0.2 times the axial thickness of the feederhole plate.

3. The die as in claim 2 in which the distance the stream of metal moves transversely is not greater than about 0.1 times the axial thickness of the feederhole plate.

4. The porthole die as in claim 1 in which the die parts are formed of tool steel and the ratio of the billet container cross-sectional area to the feederhole cross-sectional area has a value about midway between points C and D on the graph of FIG. 1 of the drawing.

5. The porthole die as in claim 1 in which the feederhole plate has integrally formed therewith a plurality of mandrels.

6. The porthole die as in claim 1 in which the shape

produced by extruding metal through the die has a wall thickness not greater than about 0.2 inch.

7. The porthole die as in claim **1** in which the shape obtained by extruding metal through the die is substantially a multi-cavity hollow panel.

References Cited

UNITED STATES PATENTS

2,135,194	11/1938	Underhill	72—269
2,157,988	5/1939	Knapp	72—269
2,266,189	12/1941	Ganoe	72—269
2,366,344	1/1945	McFadden	72—269
3,213,662	10/1965	Lenz	72—269

FOREIGN PATENTS

448,529	5/1948	Canada.

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