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(54) **DIE FOR HOT EXTRUSION.**

(57) A die for hot gas extrusion comprises, located consecutively, an inletting, a compacting, a forming and a calibrating section (1,2,3,4), respectively, and an outletting channel (5), so that $d \leq D$ and $h = (1.0\text{-}2.0)d$, where d is the diameter of a circle circumscribed around the cross-sectional profile of the calibrating section (4); D is the diameter of the cylindrical cross-section of the compacting section (2) and h is the height of the calibrating section (4). The die is intended preferably for making a particularly thin wire (ø ~ 1.0 mm) of a complex profile from deformation resistant materials.

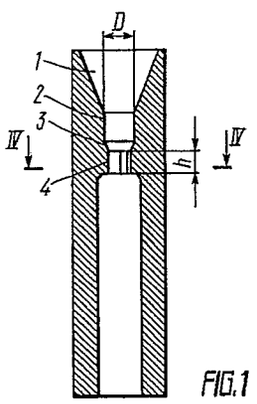

FIG.1

EP 0 434 838 A1

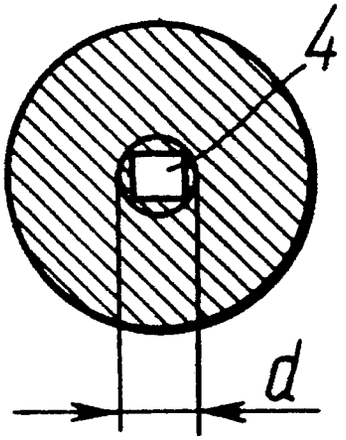

FIG. 2

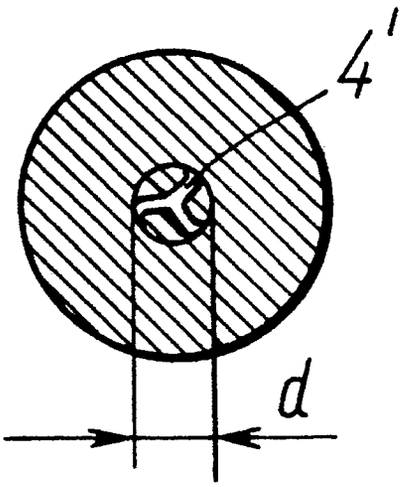

FIG. 3

DIE FOR HOT GAS EXTRUSION

Technical Field

The invention relates to plastic metal working and has specific reference to the equipment for hot gas extrusion or, to be more precise, to a die for hot gas extrusion.

Prior Art

The process of producing wire with the aid of a die plate is known far and wide. However, the deformation which is feasible to achieve per single drawing operation is small in this case so that redrawing and a lot of processing between the drawing operations (annealing, pickling, washing, drying, pointing, lubricating) are unavoidable. Apart from that, the use of the die plate is incompatible with the deformation of high-strength and brittle materials.

Widely known is the method of hot extrusion which provides for manufacturing products with a difficult cross section in a single operation, for the deformation produced in this case is greater that one resulting from drawing. But this method also suffers from appreciable drawbacks. Firstly, the blank must be of a significant diameter so that it would not cool very much in being transferred from the heating furnace into the container. This sets up a limit for minimal cross-sectional dimensions of the product and imposes a consequent limitation on the geometry of hot extrusion die. Secondly, blanks with a high length-to-diameter ratio cannot be used so that products of a restricted length only can be produced.

Hydraulic extrusion compares favourably with hot extrusion in point of stress-strain behaviour of the blank which can be consequently worked into high-quality product of difficult cross section. However, hydraulic extrusion, both cold and warm is a process of limited potentiality, for the material connot be deformed very much due to an inadequate plastic behaviour at the temperatures which can be used during hydraulic extrusion.

The method of hot gas extrusion with local heating holds out much more promise, for a greater amount of deformation can be brought about in this case. Therefore, blanks with a high lenght-to-diameter ratio can be used to produce light-gauge wire with fine-grain structure and improved physical and mechanical properties even from brittle materials which deform with difficulty.

The geometry of the die used in hot gas extrusion with local heating differs materially from that of extrusion and hydraulic extrusion dies and die plates.

Known in the art is a hot gas extrusion die ("Forging and Stamping Practices" magazine, No. 10, 1980, V.D.Berbentsev et al. "High-Temperature Gas Extrusion With Local Heating", pp. 10-12) which has a taper inlet cavity, a cylindrical sizing cavity and an outlet passage and is suitable for extruding products of circular cross section in the form of wire. However, this die is practically inapplicable for the extrusion of extra light-gauge wire (one with a diameter less than 1 mm). The point is that the leading end of the blank is compacted, preparatory to extrusion, in the sizing cavity and the results of this process vary inversely with the diameter of the cavity. A good compacting is practivally impossible in a cavity which is under 1.5 mm in diameter.

Also known is a hot gas extrusion die arranged wherein consecutively in the direction of blank travel there are an inlet taper cavity, a cylindrical sealing cavity, a forming transition cavity, a sizing cavity and an outlet passage (SU; A; 1,237,284). This die, being provided with the cylindrical sealing cavity between the inlet taper cavity and the sizing cavity, is fit for producing extra light-gauge wire under 1 mm in diameter but of the circular cross section only.

However, a need in various small-size shapes made from various materials exists nowadays in the field of engineering. Such products could be produced if the sizing cavity of circular cross section is replaced in the known die by a sizing cavity with a cross section of the requsite difficult configuration. But the conditions under which the blank deforms in this case change significantly. In a die with the sizing cavity of circular cross section the blank is in a state of axi-symmetrical stress and the product (wire) is therefore quite straight. When use is made of a die the sizing cavity whereof is of difficult cross section, the mechanism of stress-strain behaviour of the blank acquires an intricate asymmetrical pattern in the zone of transition from the cylindrical sealing cavity into the sizing cavity of the difficult cross section. The product can sustain a transverse curvature or twist about the longitudinal axis. The stresses can be relaxed by increasing the height of the sizing cavity of the die. But this would extend the period during which the blank stays in the zone of maximum temperature and cause a coarsening of the blank material. Apart from that, the quality of shapes depends to a considerable extent on the ratio of the cross-sectional areas of the sizing

cavity and the cylindrical sealing cavity and on the way in which the fairing from one cavity into the other takes effect.

Disclosure of the Invention

The principal object of the invention is to provide a die for hot gas extrusion the cavities whereof are of a geometry which would permit the manufacture of extra light-gauge wire (under 1 mm in diameter) of any difficult cross section from any materials including brittle ones which deform with difficulty.

This object is realized by disclosing a die for hot gas extrusion having a taper inlet cavity, a cylindrical sealing cavity, a forming cavity, a sizing cavity and an outlet passage located consecutively in the direction of blank travel wherein according to the invention the diameter of a circle described about the outline of the cross section of the sizing cavity is not greater than the diameter of the cylindrical compacting cavity, the height of the sizing cavity is 1-2 times the diameter of the circle described about the outline of the cross section of the sizing cavity and the forming cavity is of a varying cross section which ensures a smooth transition from the cross section of the sealing cavity, which is a circle, to the cross section of the sizing cavity.

The die for hot gas extrusion provided in accordance with the present invention operates under the combined effect of high temperatures and high isostatic pressures and is a good tool for producing long products of difficult cross section with a diameter less than 1 mm sustaining significant deformation in various materials, including brittle ones which deform with difficulty, featuring improved mechanical properties due to improved structure. The disclosed die eliminates multiplicity of operations commonly unavoidable in producing such products and significantly increases the output due to minimizing the reject.

Summary of the Drawings

A preferred embodiment of the invention will now be described by way of example with reference to the accompanying drawings, wherin:

Figure 1 is a sectional elevation of the die for hot gas extrusion according to the invention;

Figure 2 is a section on line II-II of Fig. 1 showing a square cross section of the sizing cavity;

Figure 3 is a view similar to that of Fig. 2 showing a cross section of the sizing cavity which is a circle with three recesses;

Figure 4 is a sectional elevation of the die according to the invention showing a blank which has been compacted preparatory to extrusion;

Figure 5 is a view similar to that of Fig. 4 showing the extrusion of the blank into a light-gauge wire.

Preferred Embodiment of the Invention

Referring to Figs. 1 through 3, the die has a taper inlet cavity 1, a cylindrical sealing cavity 2, a forming cavity 3, a sizing cavity 4 of a height "h" and an outlet passage 5. The cavities 1 through 4 form the contact surface of the die. The diameter, "d", of a circle described about an outline of the cross section of the sizing cavity 4 and about an outline of any cross section of the forming cavity 3 is equal or less than the diameter, "D", of the cross section of the cylindrical sealing cavity 2:

$$d \leq D$$

and the height, "h", of the sizing cavity 4 is

$$h = (1.0\text{-}2.0)d$$

The forming cavity 3 has a variable cross section ensuring a smooth transition from the cross section of the sealing cavity 2, which is of the circular outline, to the cross section of the sizing cavity 4. Referring to Fig. 2, the sizing cavity 4 is a square in cross section and, referring to Fig. 1, the forming cavity 3 is a circle in cross section at the top (entry end) and a square at the bottom (exit end). Referring to Fig. 3, the zsizing cavity 4^1 has a difficult cross section in the form of a circle with three spherical recesses spaced equidistantly apart at 120° and the forming cavity 3 is of a shape which provides for a smooth transition of the cross section of the cavity 2, having a circular outline to the cross section of the sizing cavity 4^1.

In operation, a blank 6 (Figs. 4, 5) is prepared having a taper portion 7 (the angle of taper whereof is

slightly less than that of the cavity 1 of the die) and a cylindrical portion 8 with a diameter which is slightly (by 0.05-0.10 mm) less than the diameter, "D", of the sealing cavity 2 of the die. The cylindrical portion 8 of the blank 6 is introduced into the cylindrical sealing cavity 2 of the die with an interference to obtain a gas-tight fit (Fig. 4).

In the course of extrusion the blank 6 deforms in the transition forming cavity 3, enters the sizing cavity 4 and is extruded therefrom as a light-gauge wire 9 (see Fig. 5).

The above parameters of the sizing cavity 4 have been adopted on the basis of analytical end experimental data with due regard for the specified product quality, the strenght of the die and other factors.

If d > D, an incomplete forming of the product outline will take place.

If h < 1.0d, the rpoduct may become crooked and twisted due to lack of sizing and the strength of forming cavity of the die may be impaired.

If h > 2.0d, the friction force will build up calling for an increase in the extrusion pressure. Also the contact surface of the die will get longer so that either the oyerall height of the die will increase --the rest of the parts of the hot gas extruder will increase in size as well -- or the height of the outlet passage 5 will decrease. This will bring about an over-heating of the sealing ring (not shown) in the lower part of the die and leakage of the high-temperature gas extrusion chamber. Moreover, an increase in the height of the sizing cavity 4 extends the interval of time during which the extruded metal is exposed to high temperature and causes a coarsening of the grain which impairs product quality.

For a better understanding of the essence of the present invention the results of hot gas extrusion with the use of the die according to the invention are exemplified below.

A blank with a diameter of 7.0 mm in rapid tool stell comprising (% by mass) C, 0.88; W, 6.1; Mo, 5.1; Cr, 3.8; V, 2.0; Mn, 0.28; Si, 0.48; Fe, the balance was worked into a long product with a cross section resembling that of a screw tap which could be inscribed into a circle with a diameter d = 2.0 mm. The process took place in a hot gas extrusion equipment, using a die in a hard alloy (tungsten carbide and 6% Co). The outside diameter of the die was 12.8 mm, the angle of taper of the taper inlet cavity 1 was 40°, the diameter "D" and the height of the sealing cavity 2 were 3 mm each and the height "h" of the sizing cavity 4 was 2.4 mm. The forming cavity 3 eased the change between its cross section and that of the sealing cavity 2 at one end and with the cross section of the sizing cavity 4 at the other end. The product quality was good.

The geometrical relationship between the cavities of the die were determined experimentally for various values of the diameter "d" of the circle described about the outline of the cross section of the sizing cavity 4 and the height "h" of the sizing cavity 4. For the results of the tests see Tables 1 and Table 2.

Table 1

Ref. No.	d/d	Forming of shape
1	0.5	Complete
2	0.8	Complete
3	1.0	Complete
4	1.2	Incomplete
5	1.5	Incomplete

Table 2

Ref. No.	h/d	Quality of extruded shape
1	0.3	Product rejected due to spalling of projections in sizing cavity
2	0.7	Rough surface finish, product crooked and twisted about longitudinal axis
3	0.9	Product slightly crooked and twisted with a large pitch
4	1.0	Quality product
5	1.5	Quality product
6	2.0	Quality product
7	2.5	Poor structure due to coarse grain
8	3.0	Further coarsening of grain and deterioration of structure

Industrial Applicability

The invention may be of utility in producing light-gauge wire (ø ~ 1.00 mm) of difficult cross section from brittle materials which deform with difficulty.

Claims

1. A die for hot gas extrusion having a taper inlet cavity (1), a cylindrical sealing cavity (2), a forming cavity (3), a sizing cavity (4) and an outlet passage (5) which are located consecutively, **characterized** in that the diameter (d) of a circle described about the outline of the cross section of the sizing cavity (4) is not greater than the diameter (D) of the cylindrical sealing cavity (2), the height (h) of the sizing cavity (4) is 1-2 times the diameter of the circle described about the outline of the cross section of the sizing cavity (4) and the forming cavity (3) is of a varying cross section which ensures a smooth transition from the cross section of the sealing cavity (2), which is a circle, to the cross section of the sizing cavity (4).

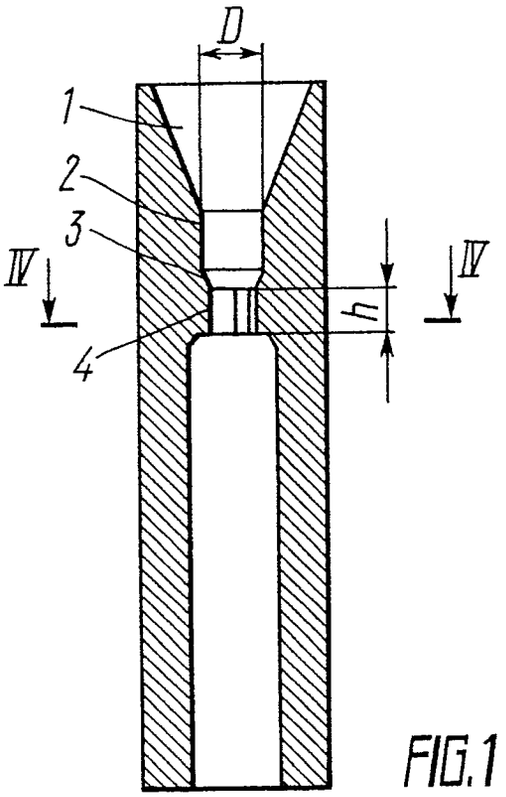

FIG.1

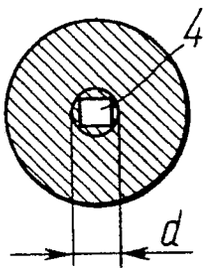

FIG.2

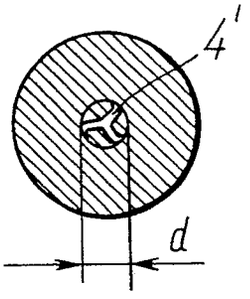

FIG.3

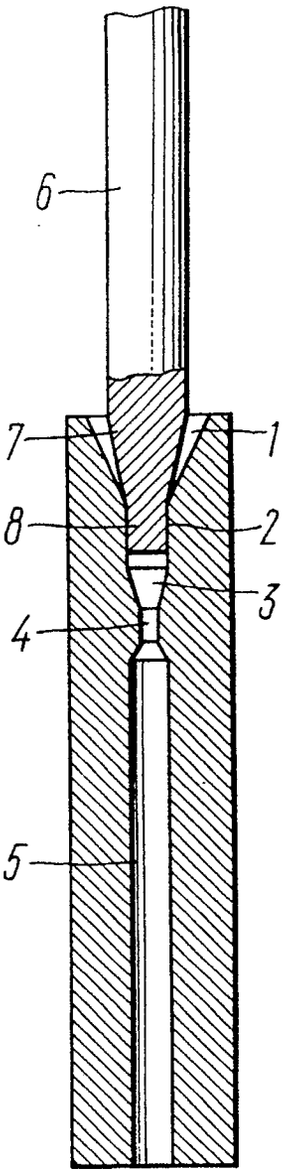

FIG.4

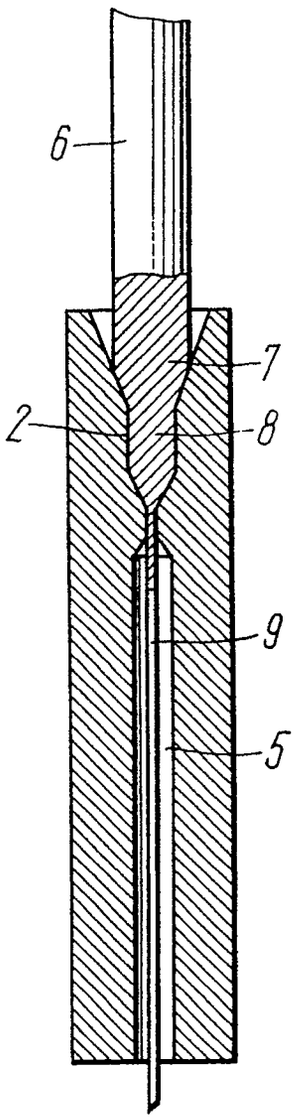

FIG.5

INTERNATIONAL SEARCH REPORT

International Application No PCT/SU 89/00128

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl.[5] B 21 C 25/02

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
Int.Cl.[5]	B 21 C 23/00, 25/02

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [10]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	SU, A1, 1237284 (Institut fiziki vysokikh davleny AN SSR) 15 June 1986 (15.06.86) see the claims, figure 1 (cited in the description)	1
A	SU, A1, 1269870 (V.D. Berbentsev et al.) 15 November 1986 (15.11.86) see the claims	1
A	SU, A1, 897360 (Sverdlovsky filial Spetsialnogo proizvodstvenno-tekhnologicheskogo bjuro"ORGPRIMTVERDOSPLAV", 15 January 1982 (15.01.82) see the claims	1

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* Special categories of cited documents: [10]

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"O" document referring to an oral disclosure, use, exhibition or other means

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
04 January 1990 (04.01.90)	09 February 1990 (09.02.90)
International Searching Authority	**Signature of Authorized Officer**
ISA/SU	