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SPINNERETS

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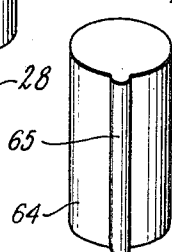
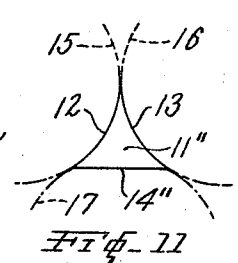
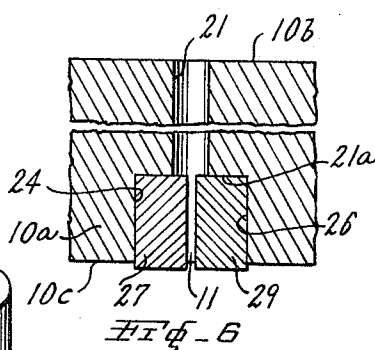
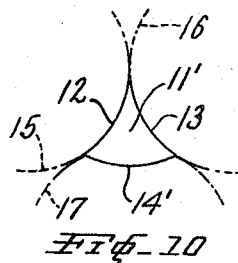
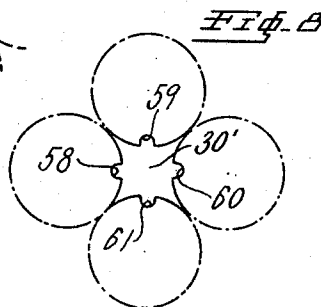
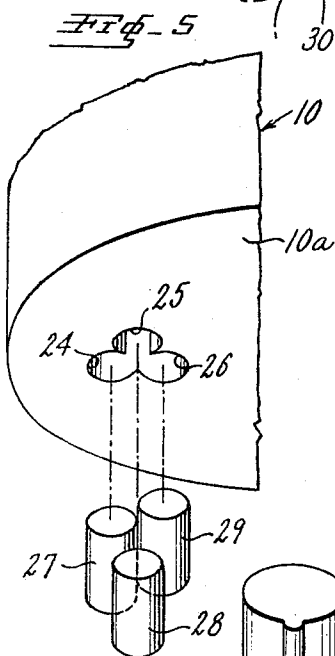
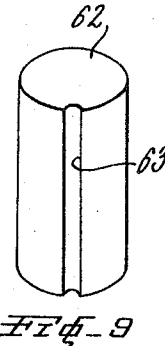
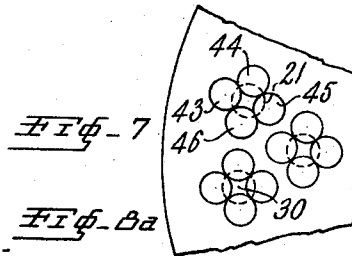
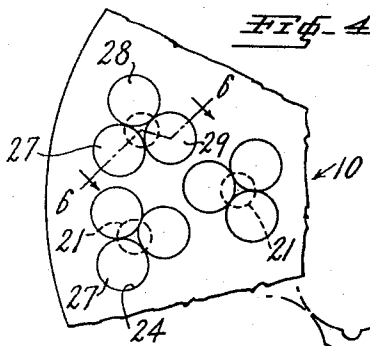
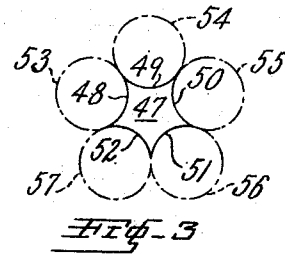
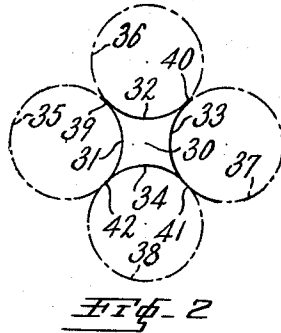
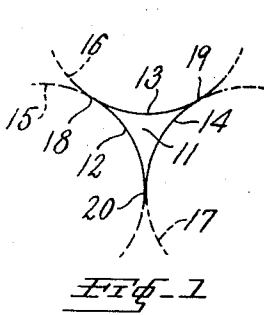


Fig. 9a

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SPINNERETS

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This invention relates to the art of manufacturing spinnerets employed in the production of artificial or synthetic filaments or fibers by extrusion processes, and particularly concerns the formation of extrusion orifices or holes of various desired cross-sections in such spinnerets.

The formation of extrusion openings or orifices of special or odd shapes, i.e. of non-circular cross-sections, in spinnerets or jet cups for synthetic filament-spinning apparatus generally entails punching and/or drilling the desired hole shapes in the metal cups or plates. Other techniques which may be employed are spark and chemical erosion of the metal, and even the use of electron beams and lasers has been attempted. See, for example, an article entitled "Spinneret Makers Enjoy Fibers Surge," in *Chemical & Engineering News*, February 1, 1965, pages 34 to 36. Such fabricating methods are, however, relatively expensive, and especially so if they fail to provide the edge sharpness and smoothness of surface finish required. Moreover, with these methods it is both difficult and expensive to achieve a high capillary ratio, i.e. the ratio of the length to the "diameter" of the orifice. In this context, the "diameter" of the orifice is the diameter of a circle which would have the same area as the non-circular opening.

It is an object of the present invention, therefore, to provide novel and improved methods for fabricating spinnerets and for forming jet openings or extrusion orifices therein.

Another object of the present invention is the provision of spinnerets having extrusion orifices of various cross-sectional shapes formed therein.

Still another object of the present invention is the provision of such spinnerets and of methods of making the same which are characterized by the attainment of smooth surface finish and high capillary ratios in the finished orifices with a minimum of expense and technical difficulty.

The foregoing and other objects, characteristics and advantages of the present invention will be more fully understood from the following detailed description thereof when read in conjunction with the accompanying drawings, in which:

FIGS. 1, 2 and 3 are graphic representations, greatly enlarged, of three types of odd cross-section spinning or extrusion orifices and illustrate the manner of construction and dimensioning thereof in accordance with the present invention;

FIG. 4 is a fragmentary bottom plan view of a spinneret provided with a plurality of jet openings or extrusion orifices having the shape illustrated in FIG. 1;

FIG. 5 is a fragmentary, exploded perspective bottom view of such a spinneret and illustrates the method of achieving the desired orifice cross-section;

FIG. 6 is a sectional view taken along the line 6-6 in FIG. 4;

FIG. 7 is a fragmentary bottom plan view, similar to FIG. 4, of a spinneret provided with a plurality of jet openings or extrusion orifices having the shape illustrated in FIG. 2;

FIGS. 8 and 8a are graphic representations of modified forms of the orifice shape illustrated in FIG. 2;

FIGS. 9 and 9a are perspective elevational views of respective elements employed in imparting to an extrusion orifice the cross-sectional shapes illustrated in FIGS. 8 and 8a; and

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FIGS. 10 and 11 are graphic representations of still other types of odd cross-section spinning orifices which can be designed in accordance with the principles of the present invention.

Generally speaking, in the production of synthetic filaments, a filament-forming material in liquid phase, e.g. either a solution in a volatile solvent or a melt, is spun by extrusion under high pressure through the jet openings or orifices of spinnerets into chambers or cabinets where the streams solidify. Such a cabinet may contain, as required, either an evaporative atmosphere such as heated air, or a liquid bath. Both dry and melt spinning systems equipped with such spinnerets for converting suitable raw materials into filaments, yarn or tow are well known and need not be illustrated or described in detail herein.

It is also well known that the jet openings or orifices of spinnerets may be circular, polygonal or otherwise cross-sectionally shaped, and that extrusion of the filament-forming material, i.e. the dope or the melt, through any such opening results in the formation of a filament having a cross-sectional shape determined in part by the shape of the opening and to a certain extent also by such factors as the nature of the material, the manner and rate of solidification of the filament, and the drawdown ratio (ratio of take-up speed to extrusion speed). Bulbous or circular cross-section filaments formed by spinning through circular orifices are the most common, of course, but for many applications, both of a textile and non-textile nature, special non-bulbous cross-section filaments are found highly desirable and advantageous by virtue of their greater surface area per filament denier, bulk, compressibility, beam strength and elasticity, and their enhanced receptiveness to dyeing and resistance to abrasion and soiling.

The present invention is principally concerned with (albeit not limited to) the manufacture of spinnerets having formed therein one or more jet openings or extrusion orifices the cross-sectional shape of which is not a circle but instead is a polygon at least one of the sides of which is essentially either flat or convex or concave viewed inwardly of the periphery of the orifice.

Thus, in accordance with one aspect of the present invention, there is provided a novel spinneret having one or more jet openings each of which is shaped substantially in the form of a triangle having inwardly convex curved sides defined by three arcuate side walls which lie along respective parts of the circumferences of three circles each contiguous, e.g. tangent, to the other two. In accordance with other aspects of the present invention, each such jet opening may have the shape of a polygon with four or more inwardly convex curved sides defined by a number of arcuate side walls which lie along respective parts of the circumferences of a corresponding number of circles each contiguous, e.g. tangent, to two of the other circles. In accordance with still other aspects of the present invention, the surface of each side wall defining such an orifice may be provided with longitudinal depressions or projections extending along the entire length of the orifice, and as desired one or more sides of each orifice may be convex while others are concave inwardly of the orifice or flat.

Referring now first to FIGS. 1 and 4-6 of the drawing, the spinneret 10 (which is generally in the form of a circular plate or similar structure) is shown as being provided, in accordance with one embodiment of the present invention, with a plurality of cusped jet openings or orifices 11 each of which is shaped substantially in the form of a triangle having inwardly curved sides 12, 13 and 14. As clearly shown in FIG. 1, the sides 12, 13 and 14 of each opening 11 constitute arcs of three circles 15, 16 and 17 which are tangent to each other at the

points 18, 19 and 20. The spinneret may be provided with as few as one and as many as several hundred such orifices, and these may be arranged and distributed throughout the expanse of the spinneret in any desired manner, for example in one or more concentric circles or in respective parallel rows and tiers, or otherwise. Each such orifice may have a "diameter" (as that term has been defined herein) between about .004 and .040 inch and preferably between about .010 and about .020 inch, and it will become clear as the description proceeds that the length of each orifice may be such as to provide a capillary ratio of length to diameter both as low as 1:1 and as high as 20:1 or more.

The spinneret 10 (see FIGS. 5 and 6) generally comprises a plate member 10a of substantial diameter and thickness, and the formation of the orifices 11, in accordance with the present invention, is as follows. Initially, a plurality of relatively wide bores 21 is drilled into the plate 10a from the top surface 10b of the latter, each such bore being located substantially in coaxial relationship with the intended location of the respective one of the desired orifices 11. The bores 21, which may have a diameter between about .0625 and about .125 inch, are conventionally formed by drilling to a depth of between about 1/2 and 3/4 of the thickness of the plate. At this point, a set of three circular bores 24, 25 and 26 is drilled into the plate 10a from the bottom surface 10c thereof all the way to the innermost end of each bore 21 along three centers located at the apices of an equilateral triangle and so spaced from each other that the three circles are tangent to one another. The innermost ends of the sets of bores 24 and 26 thus have respective, essentially prolate, segments of their circular cross-sections directly aligned with corresponding segments of the circular cross-sections of the bores 21 (see FIG. 4).

As the last one of each set of the bores 24 to 26 to be drilled reaches the level of the bottom of its associated bore 21, the respective concavely triangular rod of metal which constitutes the remains of the material drilled out of the plate from the bottom thereof becomes completely separated from the bulk of the plate and can be removed, leaving the composite opening shaped as shown in FIG. 5, the so-formed trilobar bore terminating in the plane of the innermost end of the bore 21 and the shoulder 21a surrounding the same.

Into the sets of bores 24, 25 and 26 there are then press-fitted respective sets of pins 27, 28 and 29 of the same circular diameter as the bores. The pins of each of these sets, being precisely circular in cross-section and tangent to one another, will thus define between them a cusped, concavely triangular space constituting the respective extrusion orifice 11 of the spinneret. The actual lengths of the pins 27 to 29 employed will, as previously explained, depend both on the size of the spinneret plate and on the desired capillary ratio to be attained. Merely by way of example, for an orifice 11 having a "diameter" of about 15 mils, the lengths of the pins 27 to 29 and thus the axial length of the orifice 11 would be about 300 mils where a 20:1 capillary ratio is desired. Moreover, the present invention makes it possible to increase the capillary ratio of the orifice without increasing the thickness of the spinneret plate, a result which is achieved by using pins appropriately longer than the bores 24 to 26, as indicated in FIG. 6. It will be understood, of course, that the cross-sectional size of each of the orifices 11 may be varied by appropriately increasing or decreasing the diameters of the drilled circular bores 24 to 26 (and the diameters of the corresponding pins 27 to 29), i.e. the diameters of the circles 15, 16 and 17 referred to in connection with FIG. 1.

The same principles of odd-shaped jet orifice formation are, in accordance with other aspects of the present invention, applicable to the making of spinnerets provided with one or more polygonal jet openings the shapes of which differ from that so far described. Thus, a spin-

neret (see FIG. 7) may have extrusion orifices 30 each of which (FIG. 2) has the shape of a quadrilateral with four inwardly curved sides 31, 32, 33 and 34 each of which constitutes an arc of a respective one of four circles 35, 36, 37 and 38 tangent to one another at the points 39, 40, 41 and 42. It will be apparent that in the formation of each orifice 30, after the respective bores 21 have been drilled into the spinneret plate from the top surface thereof, four bores corresponding to the circles 35 to 38 are drilled into the plate from the bottom face thereof at respective centers located at the corners of a square, so that each such bore is tangent to the two adjacent bores. Again, at the completion of the drilling of the last such bore, the concavely sided piece of solid material will be completely separated and removable from the plate, whereupon the firm insertion of rigid pins 43 to 46 of precisely circular cross-section into the respective bores will define therebetween the cusped orifices 30 having four side walls defined by the respective surface portions of the pins corresponding to the solid-line arcs 31 to 34 shown in FIG. 2. As in the case of the orifice 11, of course, the size of the orifice 30 can be varied by a suitable choice of the diameters of the circles 35 to 38 and of the pins 43 to 46 inserted into the respective bores.

Similarly, a spinneret may be made with cusped orifices 47 (FIG. 3) having five concavely curved sides 48 to 52 constituted by respective arcs of a plurality of circles 53 to 57 each of which is tangent to the two adjacent circles. The manner of formation of the orifice 47 is identical with that heretofore described for the orifices 11 and 30, to wit it is formed by initially drilling a bore corresponding to the bore 21, then drilling five circular bores tangent to one another, as indicated by the circles 53 to 57, with their centers located at the apices of a regular pentagon, and finally press-fitting a set of rigid pins of the identical diameter into each of the so-formed bores, leaving therebetween the orifice 47. It will be understood that these same techniques can also be employed for the formation of orifices having more than five sides.

In general, the cross-sectional shape of filaments spun by extrusion through such orifices as 11, 30, 47 etc. will depend among other things both on the raw material employed and the attendant extrusion conditions, and a melt spun filament extruded through a given orifice may differ in shape from a dry spun filament extruded through the same orifice. Inasmuch as such filaments and their shapes do not constitute a part of the present invention, however, they are neither illustrated nor described in detail herein.

It will further be understood that the cross-sectional shapes of any orifice of the types herein described may be varied in other ways so as to admit of the formation of still different filament cross-sections. A representative type of modification of cross-sectional shape is illustrated in FIG. 8, where a four-sided orifice 30' is shown which is generally identical to the orifice 30 of FIG. 2 and differs therefrom only in that longitudinally extending grooves 58 to 61 are formed in the side walls of the orifice. The deformations or grooves 58 to 61 can be formed by milling or otherwise suitably cutting the necessary material out of each of the pins 62 to be press-fitted into the respective bores drilled into the bottom face of the spinneret plate, as indicated at 63 in FIG. 9. Moreover, more than one such groove or slot may be provided in each side wall of the orifice, and either one or a plurality of the desired deformations may be provided on less than all the walls of the orifice. Alternatively, in lieu of grooves, each pin 64 (FIG. 9a) may be provided with one or more ribs or like projections 65 which in the finished spinneret would project from the walls of the orifice 30' (FIG. 8a) inwardly of the latter so as to alter its cross-sectional shape, accordingly.

Some other types of modifications of cross-sectional shape are illustrated in FIGS. 10 and 11 where two three-

sided orifices 11' and 11'' are shown. Each of these orifices are generally the same as the orifice 11 of FIG. 1 and differs therefrom only in that the inwardly convex side 14 is replaced in one case by a side 14' which is concave inwardly of the orifice, and in the other case by a side 14'' which is plane and not curved. Clearly, the same could be done with two or all of the sides of the orifice 11, and with any number or all of the sides of the orifices 30, 47 and 30', by the appropriate shaping of the orifice wall-defining surface of each pin involved. In any such variation, of course, wherever there is a juncture between any two sides which are not inwardly convex, the orifice is, strictly speaking, not cusped as that term is generally employed, but for the purposes of this application the term "cusped" is to be interpreted to cover such junctures as well.

It will also be apparent that the principles of the present invention extend to the formation of orifices by the drilling of circular bores of unequal diameters and in such a way that they need not be tangent to each other. Merely, by way of example, any one or more of the various circles representing such bores in FIGS. 1 to 3, 8, 10 and 11 could intersect one or both of its two adjacent circles, and in fact for some orifice cross-sections the drilling of two intersecting bores will suffice, assuming that the pins or inserts are suitably shaped at their facing surfaces to define the necessary space therebetween. Moreover, the polygonal cross-sections need not be regular and equilateral, the dimensions and shape of any orifice wall being determined solely by the amount of material removed from the pin defining that wall and by the pattern of such removal.

Still further, the principles of the present invention may also be applied to the formation of circular and straight-sided polygonal orifice cross-sections. Merely to illustrate this aspect, a circular orifice could be formed by milling into each of the pins to be inserted into a set of bores in a spinneret, e.g. the pins 27 to 29 shown in FIG. 5, respective longitudinal concavities of circular cross-sectional curvature and having identical constant radii of curvature of suitable magnitude, while a straight-sided triangle could be formed by milling respective flats onto the pins.

The present invention thus provides a novel method of forming an extrusion orifice in a spinneret which method, in its broadest essentials, is characterized by the steps of (a) drilling a set of at least two laterally contiguous bores in the spinneret plate and (b) refilling such bores with hard pins of appropriate peripheral surface contours so that there is a certain space defined between the pins which constitutes the orifice of the desired cross-sectional shape. The method of the present invention is, consequently, seen to be possessed of almost infinite versatility in respect of the types and sizes of orifice cross-sections attainable thereby, and also in respect of the attainable capillary ratios. Moreover, it is further possessed of the technological advantage of enabling an orifice of relatively small effective "diameter" to be formed through an initial formation of a plurality of considerably larger diameter bores, as will be appreciated from the fact that three bores (15 to 17 in FIG. 1 or 24 to 26 in FIG. 5) of .062" diameter make an orifice (11 in FIG. 1) of only .013" diameter.

As previously indicated, the number of jet openings or orifices in any given spinneret may be as high as several hundred, and thus the total denier of the filamentary material collected from each spinneret will depend both on the number and sizes of the orifices. In accordance with the present invention, it is also possible to provide in any given spinneret a plurality of orifices of different cross-sections so as to provide for the formation of a filament bundle composed of a mixture of filaments of correspondingly different cross-sections. Merely by way of example, a spinneret may contain any two or more of the types of orifices 11, 30, 47, 30' etc. of the present invention, or any one or more of these types intermingled with one or more orifices of any other shape, such as circular orifices, crescent-shaped orifices, etc.

The orifice-defining metal pins are preferably hardened and, since they can be extruded or machined within relatively close tolerances, make possible the formation of orifices of precisely predetermined dimensions and highly smooth interior surface finishes. Various techniques can also be used to prevent any leakage of the filament-forming material around the pins. Merely by way of example, if hardened pins are inserted in a relatively softer metal spinneret plate, finish grinding of the lower surface of the latter will cause the softer metal to flow over the pins where they adjoin the plate. This will have no adverse effect on the sharpness of the end edges of the capillary walls, however, since the hardened metal of which the pins are made will resist the tendency to flow under grinding. Alternatively, the pins may be silver-soldered in place to effect the required seal.

Spinnerets having orifices of the types herein set forth may be employed in spinning substantially all known filament-forming materials, including nylon, rayon, acetate, polyesters, acrylonitrile polymers and copolymers, polymers and copolymers of olefins and vinyl esters such as ethylene, propylene, vinyl chloride, vinylidene chloride, vinyl acetate, etc., ethyl cellulose, and the like.

In an actual test, a spinneret having formed therein 35 orifices of the type shown in FIGS. 1 and 4 and each defined between a respective set of three hard-surfaced $\frac{1}{16}$ inch diameter steel pins press-fitted into corresponding drilled holes and having a capillary length of $\frac{3}{16}$ inch to yield a capillary ratio of better than 14:1, was employed in a melt spinning operation. The raw material was polypropylene furnished by Hercules Powder Company. The extruder temperature was 540° F., the extruder pressure 3700 p.s.i., the spinning head temperature 510° F., the spinning rate 7 pounds per hour, and the drawdown ratio of 5.09. After a continuous run of 51 hours and 50 minutes, approximately 360 pounds of a convexly triangular cross-section filament yarn had been produced with a denier of 210 and a tenacity of 5.35 grams per denier. This yarn had acceptable dyeability and is highly suited for use in the manufacture of upholstery, carpeting, clothing and drapery fabrics.

It is to be understood that the foregoing disclosure is for purposes of illustration only, and that the various structural and operational features, relationships and conditions set forth in detail herein are subject to modification in a number of ways none of which involves a departure from the spirit and scope of the present invention as defined in the hereto appended claims.

Having described my invention, what I claim and desire to secure by Letters Patent is:

1. A spinneret provided with at least one cusped extrusion orifice having at least three side walls which are convex inwardly of the orifice, said orifice being defined between a set of pins of circular cross-section arranged in a ring formation with each pin tangent to two of the other pins, and said walls of said orifice being constituted by the minor arcs of the circumferential pin surfaces lying between their points of tangency.
2. A spinneret having at least one extrusion passageway terminating in an orifice of odd cross-sectional shape, said passageway comprising a first bore extending in from one face of the spinneret through a predetermined portion of the thickness thereof, and said orifice being in communication with and extending from the inner end of said first bore to the other face of said spinneret, said orifice being of cusped cross-sectional shape and having at least three side walls which are convex inwardly of the orifice, said orifice being defined between a set of pins of circular cross-section arranged in a ring-like formation with each pin tangent to two of the other pins, and said walls of said orifice being constituted by the minor arcs of the circumferential pin surfaces lying between their points of tangency.
3. A spinneret having at least one extrusion passageway terminating in an orifice of odd cross-sectional shape, comprising a plate provided with a first circular bore

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drilled in from one face of said plate through a predetermined portion of the thickness of said plate, and with at least three additional circular parallel bores, each tangent to two of the other additional bores, drilled in from the other face of said plate to the inner end of said first bore and on respective centers located at the corners of a polygon substantially enclosing the cross-section of said first bore, and a like number of hardened metal pins of the same diameter as said additional bores tightly fitted into the latter, thereby to define a cusped orifice having inwardly convex walls constituted by the minor arcs of the circumferential pin surfaces lying between their points of tangency.

4. A spinneret according to claim 3, wherein said pins are three in number and are fitted into three of said additional bores centered at the apices of a triangle, and said orifice has the cross-sectional shape of a triangle with inwardly convex sides.

5. A spinneret according to claim 3, wherein said pins are four in number and are fitted into four of said additional bores centered at the corners of a quadrilateral, and said orifice has the cross-sectional shape of a quadrilateral with inwardly convex sides.

6. A spinneret according to claim 3, wherein said pins are five in number and are fitted into five of said additional bores centered at the corners of a pentagon, and said orifice has the cross-sectional shape of a pentagon with inwardly convex sides.

7. A spinneret according to claim 3, wherein there are provided a plurality of additional orifices at least some of which are identical to said first-named orifice.

8. A spinneret according to claim 3, wherein on the orifice wall-constituting surface portions of at least some of said pins there is provided at least one surface deformation changing the orifice cross-section correspondingly.

9. A spinneret according to claim 8, wherein said deformation comprises a surface depression.

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10. A spinneret according to claim 8, wherein said deformation comprises a surface protuberance.

11. A spinneret having at least one extrusion passage-way terminating in an orifice of predetermined cross-sectional shape, comprising a plate provided with a first circular bore drilled in from one face of said plate through a predetermined portion of the thickness of said plate, and with at least three additional circular parallel bores, each contiguous to two of the other additional bores, drilled in from the other face of said plate to the inner end of said first bore and on respective centers located at the corners of a polygon substantially enclosing the cross-section of said first bore, and a like number of hardened metal pins of the same basic diameter as said additional bores tightly fitted into the latter, those parts of the circumferential surfaces of said pins bounding the region therebetween being appropriately shaped to define between their points of contact a space constituting said orifice.

12. A spinneret according to claim 11, wherein at least one of the sides of said orifice is inwardly convex.

13. A spinneret according to claim 11, wherein at least one of the sides of said orifice is inwardly concave.

14. A spinneret according to claim 11, wherein at least one of the sides of said orifice is flat.

References Cited by the Examiner

UNITED STATES PATENTS

1,773,969	8/1930	Dreyfus et al.	18—8
1,902,953	3/1933	Hazell	18—8 X
2,422,994	6/1947	Taylor.	
3,095,258	6/1963	Scott	18—8 X
3,102,439	9/1963	Martin et al.	76—107
3,174,364	3/1965	Sims	18—8 X
3,197,812	8/1965	Dietzsch et al.	18—8

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