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Turner

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[54] SPINNERETTE FOR PRODUCING HOLLOW FILAMENTS

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[52] **U.S. Cl.** ....**425/461**, 264/177 F

[51] **Int. Cl.** **D01d 3/00**

[58] **Field of Search** ....264/177 F; 18/8 SS

[56] **References Cited**

UNITED STATES PATENTS

3,187,607	6/1965	Krummeck	18/8 SS
3,323,168	6/1967	Drunen et al.	18/8 SS

FOREIGN PATENTS OR APPLICATIONS

1,009,625	11/1965	Great Britain	264/177 F
690,619	7/1964	Canada	264/177 F
23,616	8/1962	Germany	264/177 F
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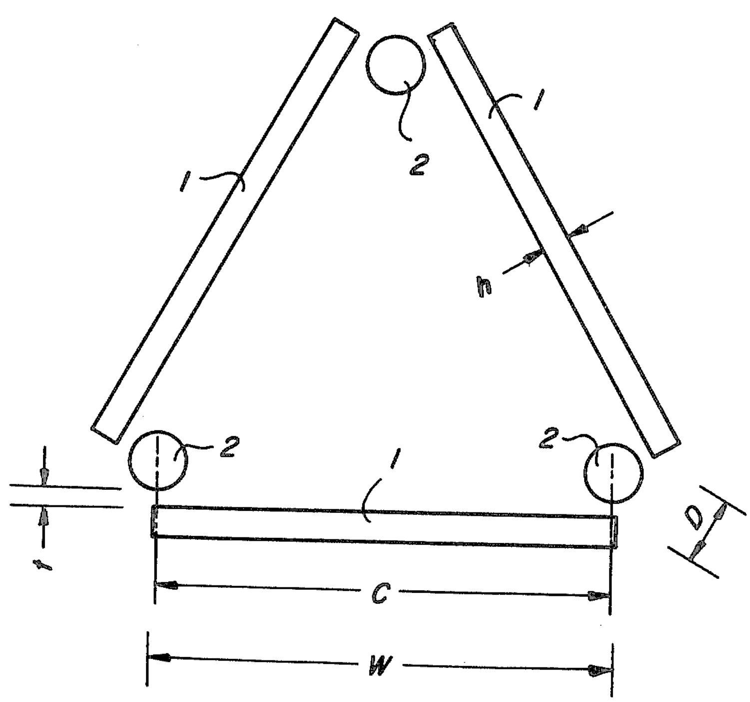
[57] **ABSTRACT**

A spinnerette for spinning hollow filaments having a maximum amount of hollow space in relation to the outer dimensions of said filaments. The filaments are extruded from a group of preferably three slots and corresponding three round openings or dots. The polymer occluding area defined by the arrangement of the slots forms substantially an equilateral triangle. The round openings are arranged near or at the ends of the slots, but not in communication with the slots. Filaments melt spun from the nested embodiment of this spinnerette consistently have above 35 percent hollow space. The spinnerette is much less subject to breakage than similar designs. Specific parameters for spinning with such an orifice configuration are set forth.

8 Claims, 2 Drawing Figures



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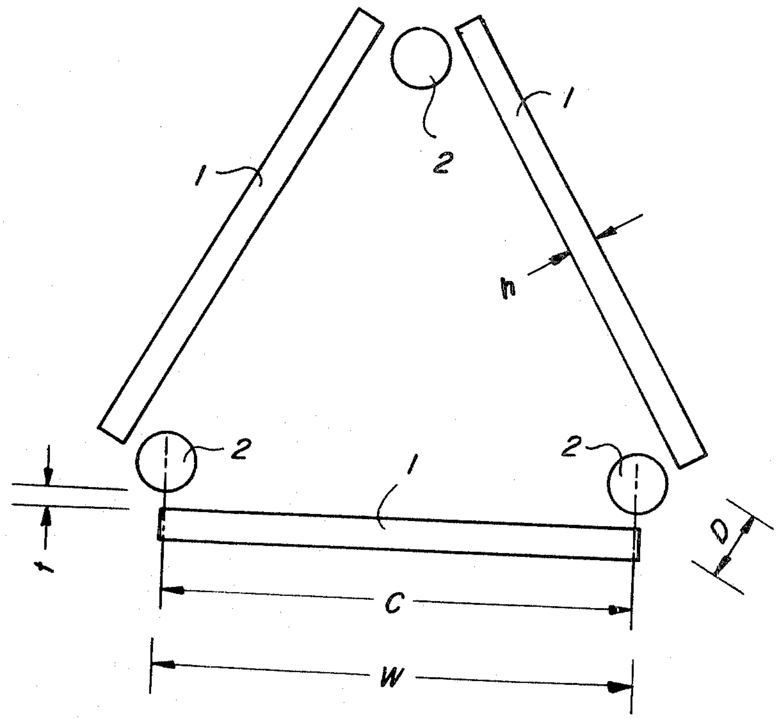

FIG. 1

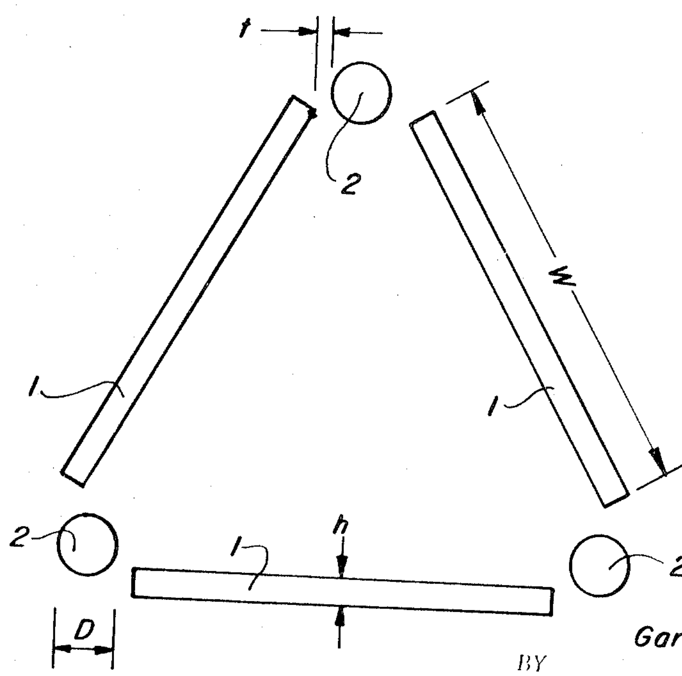

FIG. 2

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SPINNERETTE FOR PRODUCING HOLLOW FILAMENTS

BACKGROUND OF THE INVENTION

This invention is related to a spinnerette hole configuration for producing shaped hollow filaments from synthetic fiber-forming compositions.

The textile industry has long been interested in hollow filaments because of the special attributes of such fibers and the several novel effects which may be obtained with them. It is well recognized that hollow filaments have certain advantages over solid filaments having the same outer diameters. Some of the advantages which hollow filaments have over solid filaments include: improved insulation properties, increased bouyancy, reduced pilling, special optical effects, and greater covering power per unit weight. Hollow filaments also have less tendency to fibrillate under flexing conditions than corresponding solid filaments.

While hollow filaments are highly desirable by the textile industry, it has proved to be extremely difficult to manufacture these filaments in a commercially feasible manner by melt-spinning. Considerable time and effort have been spent on attempts to adapt existing methods to the production of hollow filaments on a commercial scale. Processes which have been devised for this purpose have necessitated the use of special and often expensive processing conditions and equipment.

Most of the problems involved with the spinning of hollow filaments are related to the spinnerette. Unfortunately, the spinnerettes that have been designed thus far are difficult to construct and are subject to frequent breakdowns which may be attributed at least in part to their complex construction.

One type of spinnerette commonly used to produce hollow filaments employs orifices containing an internal obstructing member which causes the orifice to function as an annulus. The obstructive members are usually joined to the spinnerette body by internal support members upstream from the extrusion face of the spinnerette. This type of spinnerette is difficult to make and presents a major problem in repair and cleanliness.

There are other spinnerettes available that employ a multitude of unobstructed orifices grouped in a perimeter. For example see British Pat. No. 1,009,625. See also copending U.S. application Ser. No. 687,710, filed Dec. 1, 1967. The orifices exist in various cross-sectional shapes such as trislot modified triangular, circular, rectangular crescent shape or other curvilinear or polygonal shapes spaced in close proximity to essentially circumscribe an area of the spinnerette plate. The circumscribed area blocks the flow of extrudate as the molten polymer streams emerging from the closely spaced orifices coalesce to form hollow filaments. These spinnerettes require very close spacing between adjacent orifices to permit proper coalescence of the extrudate streams with the result that the thickness of the web of intervening metal between orifices is so small as to cause structural weakness and difficulties with fabrication. Thus, the weakened nature of these spinnerettes is particularly significant in the melt-spinning of synthetic fibers because the extrusion pressures required will often cause distortion or actual rupture of spinnerettes which are not properly designed. Another serious problem encountered with orifices spaced too closely is that polymer coalescence may occur too close to the spinnerette face thus preventing the entrance of air into the hollow cavity of the filament. Therefore, the resultant vacuum within the filament causes internal coalescence of the molten polymer which minimizes or completely eliminates the central cavity.

SUMMARY OF THE INVENTION

The principal objective of the present invention is to provide a spinnerette for producing hollow filaments having the maximum internal cavity obtainable within a given filament. It has been found that these objects among others can be achieved through the use of a spinnerette having at least one group of at least three slots, and a corresponding equal number of round openings or dots arranged so that a substantially equilateral polygonal area is circumscribed by the slots which produce an orifice. The round openings or dots are spaced from the slots at or near the apex of each angle. The preferred configuration is three slots and three dots used to form a triangle. Because the orifice configuration of this invention permits entry of air from at least six points, this invention also overcomes the problem of vacuum within cavity of the filament. Spinnerette capillaries made from combinations of slots and round holes offer a more simple geometrical form which are easier to manufacture than intricate designs which are now used. This combination can be fitted to any design to give better flow and fusing of the individual parts than the trislot type due to the minimizing of the "end effects" which are present in long, narrow slots.

The round opening or dot portion serves several functions. Because the round openings or dots relieve pressure at corner stress points, the spin head holes of this invention very seldom explode, implode or sink at one corner portion. Another important function is the fact that the proper amount of air enters the cavity of the hollow filament while maintaining superior fusing or coalescing of filament sides and proper polymer flow. Also using the preferred embodiment as an example, a substantially equilateral triangular polymer occluding area is formed which contributes to the maximum amount of open or hollow space within the filament cross section. Another important result achieved by this particular arrangement and configuration of slots and openings is the fact that the walls of the hollow filaments are quite uniform. Because of the round openings at or near the apex of each angle there are no large areas formed at the apices or points where coalescence occurs.

The product obtained from the practice of this invention is a synthetic filament consisting of a polygonal-shaped sheath and an internal, longitudinally extending, polygonal cavity centrally disposed with respect to the filament axis and the peripheral contour of the cross section of the cavity being the shape of the area occluded at the die face. The shapes of both the cavity and sheath will be essentially constant along the length of the filament. The cavity may occupy up to about 60 percent of the entire cross-sectional area of the filament depending upon the width and length of the slots. Even with low-viscosity polymers a high percent hollow filament can be formed.

The slot-dot configuration of this invention can provide a filament having a cross-sectional variance in polymer crystal orientation due to the different attenuations through the slots as compared to the dots. This makes an easily crimpable fiber by merely stretching the filament.

The filaments produced by the slot-dot configuration have potentially desirable optical properties for uses in apparel and carpeting.

Thermoplastic polymers suitable for use in the present invention include most of the fiber-forming melt-spinnable compositions. These compositions which are preferred include polyesters, such as polyethylene terephthalate and polyhexahydro p-xylylene terephthalate; polyamides such as a polyhexamethylene adipamide and polycaproamides; polyolefins, such as polyethylene and polypropylene, polyurethanes; polyesteramides; polyethers; and other synthetic polymers and mixtures thereof.

Filaments produced by the spinnerette of the present invention have been found to be extremely useful for flotation materials because of their low-density cross section. They may be used in the form of monofilament and multifilament yarn, tow, cords, and staple spun yarns. The filaments may be blended with other fibrous materials, and may be employed in crimped or uncrimped conditions.

Other typical textile applications include apparel products such as woven suitings, shirtings, sheeting and lingerie, tricot, circular knitted fabrics, broadcloths, satins, and the like. In view of their relatively high stiffness, strength, and low weight, the filaments of this invention are further useful in textile applications such as sewing thread, tire cord, fiber-reinforced laminates, upholstery, carpeting, drapery, curtains, ducks, parachutes, reinforced belts and hoses, marine lines, ropes and netting, and other applications. The filaments may be admixed with solid core filamentary structures of various modified cross section of the same or different denier and the same or different chemical composition to produce various special effects.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a fragmentary section of a spinnerette plate illustrating the preferred arrangement and configurations of a group of slots and nested round openings or dots forming an orifice in accordance with this invention.

FIG. 2 is another fragmentary section of a spinnerette plate illustrating another embodiment with the dots in an end-on configuration with the slots.

TERMINOLOGY

Following are some terms which will be used here in slightly different form than in common usage.

Hole—An opening or set of openings which are common to a single counterbore and produce a monofil.

Web—A narrowed solid portion of a spinnerette hole area which lies between adjacent openings. For example, the narrowest dimension between a slot and a dot shown as t in FIG. 1 and FIG. 2.

Slot—A part of a spinnerette hole which has a greater length than width.

Capillary or Dot—A part of a spinnerette hole which is round.

Configuration—Spinnerette holes of this invention are formed by combinations of slots and capillaries or dots, and preferably take the form of an equilateral triangle. See FIGS. 1 and 2. The capillaries (dots) may be end-on to the slots (FIG. 2) or nested between slots (FIG. 1). The slots are labeled 1, and dots 2 in both figures. The dimensions are shown as:

h = width of slot
t = width of web at narrowest portion
D = diameter of dot
C = distance between centers of dots
W = length of slot

The nested dots-type hole (FIG. 1) has consistently produced filaments of greater than 35 percent void area. Ease of fabrication of these holes has been very good.

Flow and velocity ratios of hole components have been found to be fairly critical. The following equations have been used in defining these ratios.

1. $Q \text{ dot} = (\pi R^4/8L)\cdot(P/\mu)$; $Q \text{ slot} = (Wh^3/12L)\cdot(P/\mu)$

When determining the ratios of dot/slot it is assumed that P/μ is a constant.

2. $V \text{ slot} = (h^2P/12L\mu)$; $V \text{ dot} = R^2P/8L\mu$

Q = mass flow
W = Length
V = Velocity
h = width of slot
K = constant
L = depth of slot: dot
P = pressure drop
μ = viscosity of melt
R = radius of dot = $D/2$

It has been found that Q slot/Q dot should be between 1 and 3 V dot/V slot must not exceed 3. The preferred ratios are: Q slot/Q dot = about 2 and V dot/V slot = about 2. =about 2.

SPINNERETTE HOLE PARAMETERS FOR POLYCAPROAMIDE

Webs

Width—It has been found that the web width (t) i.e., narrowest dimension between slots and dots, must be between 1 and 10 mils. and preferably between 2 and 4 mils. The low end has two determining factors: (1) enough spinnerette web material has to remain to provide support for the center section against the extrusion pressure, and (2) enough space has to be provided for the passage of sufficient air to prevent collapse of the center cavity. As the upper limit is approached problems of closure become more acute. About 3 mils. thickness has been found to be the optimum.

Number—While it has been seen that the more webs there are, the larger hollow area one may obtain; it can be said that probably not more than six are desirable or needed. First of all in the "slot-dot" spinnerette where there are six webs, there was a gain of 7 to 10 percent in hollow area when the sides are in a similar position (dots end-on as in FIG. 1) to a spinnerette which has only three webs. Then if the dots are placed in a "-nested" position relative to the dots, an additional 10 percent hollow is obtained (consistently 35–37 percent). A hollow area of more than 35 percent may not be very useful; since the walls of the filament become very thin, and the filaments are subject to deformation in subsequent operations of drawing and texturizing. An additional reason for not exceeding six webs is that manufacturing costs would increase and uniformity decrease due to the increasing complexity of the spinnerette hole. In determining web thickness (t), it is necessary to balance (1) amount of air passing to the hollow cavity of the filament across the web, (2) ability of the sides of the filament to close by coalescence or continuous fusing to each other, and (3) strength of the die face. It has been found that the web thickness (t) should be about one-half of the slot width (h).

Slots

Length—The limits of length (W) in practice have been between 30 and 100 mils. At the low end of this range a very rounded filament with a very low amount of void area resulted. Above 100 mils. the possibility of collapse increases and the stack draw down to standard filament dimensions would become prohibitive due to increased orientation with a resultant loss of drawability.

Width—Limits for width (h) fall between 3 mils. and 10 mils. Slots which are less than 3 mils. wide are very difficult to fabricate and also present spinning problems due to potential blockage by contaminants or other particulate matter which is often present in an extrudate. Slot widths of between 4 and 7 mils. are preferred.

Length-Width Ratio—Within the limits of slot length and width discussed, it has been found that probable operating ranges of the ratio of slot length to width are between 10 to 20 for a slot-dot configuration (six webs). For ratios below 10 the resulting filament becomes rounded with a reduced hollow area. Above the upper limit mentioned, an inward collapse of the walls may occur, again resulting in a reduced hollow area and loss of cross section identity.

Dots—It has been determined empirically that the radius ($D/2$) of the dots is preferred to be substantially equal to the slot width (h); but can vary between 2 and 12 mils., preferably 2 and 8 mils.

Summary of Spinnerette Hole Parameters

Certain spinnerette hole parameters have been determined empirically. When designing spinnerette holes it is necessary to consider the uniformity of fabrication for large numbers of holes as well as whether the spinnerette will produce the proper cross section on a smaller scale project. Typical dimensions for an end-on configuration as shown in FIG. 2 would be:

t=0.003 in.
h=0.005 in.
D=0.013 in.
W=0.070 in.

In the configuration of FIG. 2 the centers of the dots 2 are aligned directly with the inside edge of the slot 1. The dots 2 could be arranged in any end-on configuration, such as aligned with the slot 1 centerline, or the outside edge or beyond.

The preferred configuration is the nested arrangement shown in FIG. 1. Typical dimensions would be:

t=0.0028 in.
h=0.006 in.
D=0.013 in.
W=0.095 in.
C=0.090 in.

In FIG. 1 the dots are preferably arranged with each circumference within the sides of the angle described by the inside edges of adjacent slots. Particularly preferred is the configuration shown in FIG. 1, i.e., the circumference of each dot is tangent to an imaginary line between the nearest adjacent corners of the slots, and equidistant therefrom. The arrangement of slots in relation to dots is essential to proper operation. For example, by extending the slots beyond the nested dots it was found that good closure (coalescence or fusing sides to each other) is assured but that the cavity collapses because insufficient air is drawn into the hollow portion of the filament and a resultant vacuum is formed.

The parameters determined are applicable to all polyamides. However, for other polymers the ratios and dimensions can be determined according to the melt characteristics during spinning. For example, polypropylene is known to have a very pronounced bulge at the spinnerette hole, requiring larger width.

PROCESS CONDITION EFFECTS

Melt Temperature/Melt Viscosity—Within the practical process boundaries of a given polymer/spinnerette system, melt temperature can be varied to produce closure and exhibit some control over the targeted void area. A low-melt temperature may help in closure, in increasing void area, and to produce a better defined cross section; but one must not go so low as to affect the drawability of the product. As the melt temperature is increased the melt becomes more mobile producing some smoothing of the cross section and reduction in void area, which in many cases is desirable. For polycaproamide, a temperature of from about 240° to about 290° C., preferably 255° to 275° C. is used.

Quench—The quenching medium can be utilized in conjunction with the melt temperature effect as a process control of apparent melt viscosity to control void area. In order to be effective in this respect for polyamide the quench medium must be introduced near the spinnerette face. Quench medium temperatures of 0° to 40° C. are used.

Throughput—The major effect of throughput is that an increased flow has the same effect as a temperature increase. This is evidenced by a rounding of the cross section and a decrease in void area. Therefore quench becomes more difficult, but more necessary if the desired hollow area is to be obtained. With certain designs of spinnerettes the increased jet velocity may lead to doglegging of the melt stream as the throughput is increased. Thus at high throughput rates it is mandatory that spinnerette quality be rigidly maintained. For polyamide a throughput of 0.1 lb./hr./hole to 0.75 lb./hr./hole and preferably 0.4 to 0.6 lb./hr./hole is used.

Additives—Additives cause effects that tend to affect the melt viscosity and surface tension of the melt.

Drawing—As the amount of void area increases the amount of filament deformation increases. This is not a really serious problem at void areas less than 30–35 percent.

Summary of Process Conditions—During the spinning of hollow cross section filaments, process conditions must be set on the basis of their rheological effect on the filament. In subsequent treatments such as drawing and texturizing possible mechanical effects must be considered.

Process conditions determined are applicable to polycaproamides. For other polymers, the conditions can be determined according to melt characteristics during spinning. For example, nylon 6,6 (polyhexamethylene adipamide) spinnerette temperature would range from about 280° to 310° C.

Examples—The following table shows examples of this invention. Conditions were conventional for melt-spinning nylon, at conventional extrusion rates, 250°–290° C. head temperature, 70° F., 65 percent RH cocurrent quench air.

EXAMPLES

Design Number	Slot		Dot diameter[1]	Q slot / Q dot	V dot / V slot	Web[2] width[1]	Remarks	Hollow percent
	Length[1]	Width[1]						
0 (End on)	71	5	8	7.5	1	3	Not operable	
I (End on)	70	5	13	1	2.54	3	Very intermittent.	25
II (End on)	70	5	13	1	2.54	3	do	25
III (Nested)	90	5	13	1.33	2.54	3	Operable	>35
IV (Nested)	100	5.5	13	1.97	2.10	2.5	do	>35
IV(a) (Nested)	100	6.0	13	2.54	1.77	2.5	do	>35
IV(b) (Nested)	100	6.5	13	3.25	1.50	2.5	Not operable	
IV(c) (Nested)	95	5.5	13	1.77	2.10	2.5	Operable	>35
V (Nested)	63	4	9	2.08	1.91	2.5	do	>35
VI (Nested)	93	6	13	2.29	1.77	3	do	>35

[1] Mils.
[2] Narrowest dimension of web area.

I claim:

1. A spinnerette for extruding molten synthetic thermoplastic polymers to provide triangular-shaped hollow filaments comprising
 a plate containing at least one group of
  three slots and
  three dots

said slots being spaced in close proximity to form a triangle, each of said dots aligned on the ends of the ends of said slots with the center of each dot directly aligned with the inside edge of said slot said slots and dots being spaced so that air is admitted to the inside of said triangle during extrusion and coalescence occurs between the streams of polymer exiting said slots and dots to form triangular-shaped hollow filaments.

2. The spinnerette of claim 1 wherein the triangle is equilateral.

3. The spinnerette of claim 2 wherein said dots are arranged with each dot circumference within the sides of the angle described by the inside edges of the adjacent slots.

4. The spinnerette of claim 3 wherein the circumference of each dot is tangent to an imaginary line between the nearest adjacent corners of said slot, and equidistant therefrom.

5. The spinnerette of claim 2 wherein the narrowest dimension between said slots and dots is between about 1 and about 10 mils., the length of said slot is between about 30 and about 100 mils., the radius of the dot is between about 2 and about 12 mils., and the width of said slots is between about 3 and about 10 mils.

6. The spinnerette of claim 5 wherein the ratio of the length of the slot to the width of the slot is between about 10 to about 20, the radius of the dot is substantially equal to the slot width, and the thickness of the narrowest dimension between the slots and the dots is about one-half the slot width.

7. The spinnerette of claim 6 wherein said slot width is between about 4 and about 7 mils., the narrowest dimension between said slots is between about 2 and about 4 mils., and the radius of the dot is between about 2 and about 8 mils.

8. The spinnerette of claim 5 wherein the length of the slot is 0.095 inches, the width of the slot is 0.006 inches, the diameter of the dot is 0.013 inches, the narrowest dimension between the slots and the dots is 0.0028 inches, and the distance between the centers of the dots is 0.090 inches.

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