Nov. 17, 1970 | P. R. ROBERTS ET AL | 3,540,114

METHOD OF FORMING FINE FILAMENTS

Filed Nov. 21, 1967

FIG.1

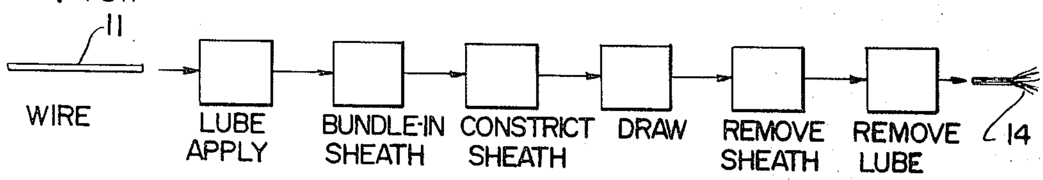


FIG.2

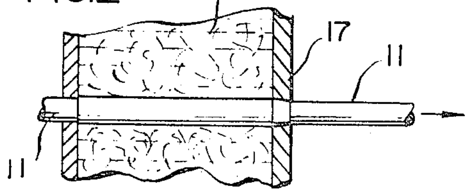


FIG.3

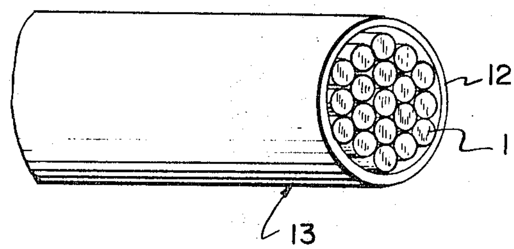


FIG.4

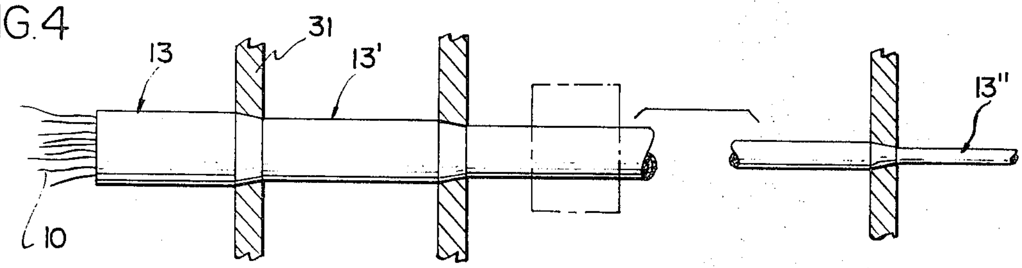


FIG.5

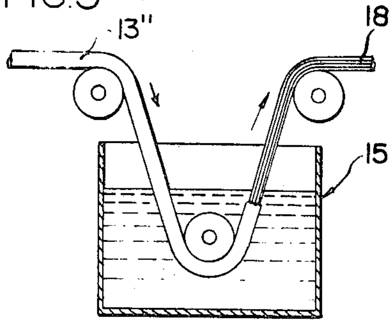
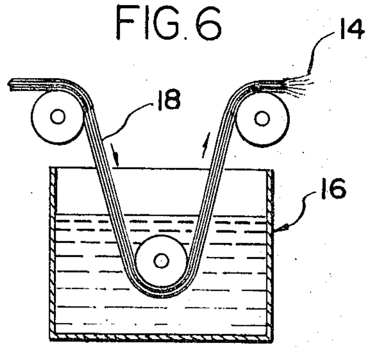


FIG.6



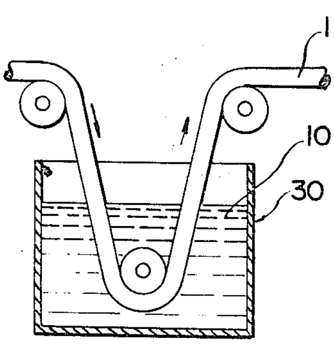


FIG.7

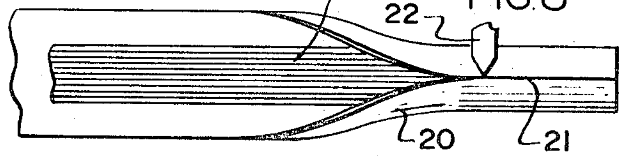
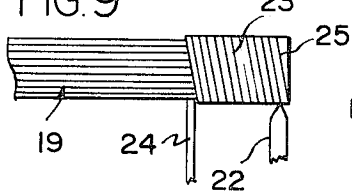


FIG.8

FIG.9



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METHOD OF FORMING FINE FILAMENTS

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ABSTRACT OF THE DISCLOSURE

A method of forming fine filaments formed of a material such as metal by multiple end drawing a plurality of elongated elements having thereon a thin film of lubricant material. The plurality of elements may be bundled in a tubular sheath formed of drawable material. The lubricant may be applied to the individual elements prior to the bundling thereof and may be provided by applying the lubricant to the elements while they are being individually drawn through a coating mechanism such as a drawing die. The lubricant comprises a material capable of forming a film having a high tenacity characteristic whereby the film is maintained under the extreme pressure conditions of the drawing process. Upon completion of the constricting operation, the tubular sheath is removed. If desired, the lubricant may also be removed from the resultant filaments.

This invention relates to fine filaments and in particular to the forming of fine filaments by a multiple end constriction process.

An improved method of forming fine filaments is disclosed and claimed in the Webber and Wilson U.S. Letters Patent No. 3,277,564, issued Oct. 11, 1966. In the method thereof a plurality of elongated elements such as metal rods is provided with suitable sheathing material and placed in a tubular outer sheath to define a billet which is subsequently constricted as by drawing to reduce the diameter of the billet, and correspondingly the diameter of the elongated elements, whereby the elements may have an extremely small diameter such as under 12 microns. The sheathing material and tubular outer sheath are subsequently removed, leaving the fine filaments which may be utilized in the manner of a textile material.

The present invention comprehends an improved method of forming such filaments wherein substantial economies may be effected in the use of a novel matrix means which may be readily and economically provided on the elongated elements and which may be readily and economically removed therefrom.

The present invention further comprehends such an improved method of forming fine filaments wherein the matrix means permits separability of the filaments without removal thereof from the filaments if so desired.

Thus, a principal feature of the present invention is the provision of a new and improved method of forming fine filaments.

Another feature of the invention is the provision of such a method of forming fine filaments utilizing an ultra-thin film matrix means.

A further feature of the present invention is the provision of such a method of forming fine filaments wherein the film matrix means comprises a lubricant material.

Still another feature of the present invention is the provision of such a method of forming fine filaments wherein the matrix comprises a film of lubricant material having a high tenacity characteristic capable of maintaining the film under extreme pressure conditions.

Yet another feature of the present invention is the provision of such a method of forming fine filaments wherein the elongated elements are bundled in a tubular sheath formed of a drawable material and the sheathed bundle is constricted as by drawing to reduce the elements to a filamentary diameter while the elements are maintained separate by the maintained film of lubricant thereon.

Still another feature of the present invention is the provision of such a method of forming fine filaments wherein the lubricant material comprises a material such as oil, grease, soap, silicone, plastics such as Teflon, and the like.

A yet further feature of the present invention is the provision of such a method of forming fine filaments wherein the sheath may be formed of a material having a hardness equal to or greater than the hardness of the elements.

Still another feature of the present invention is the provision of such a method of forming fine filaments wherein the elements comprise metal wires of relatively small commercially available diameter.

A further feature of the present invention is the provision of such a method of forming fine filaments wherein the elements are loosely placed in the sheath and the sheathed bundle is firstly constricted to compact the assembly without substantial constriction of the elements.

A yet further feature of the present invention is the provision of such a method of forming fine filaments wherein the lubricant material is provided on the elements prior to the provision thereof as a bundle.

Another feature of the present invention is the provision of such a method of forming fine filaments wherein the lubricant comprises a high temperature resistant material and the constricting step comprises a plurality of constricting operations with heat treating of the constricted bundle therebetween.

Yet another feature of the invention is the provision of such a method of forming fine filaments further including the step of plating the elements with a metal prior to the bundling thereof.

A further feature of the present invention is the provision of such a method of forming fine filaments wherein the bundle of elements occupies substantially 91% of the inner cross-section of the sheath prior to the constricting operation.

Yet another feature of the present invention is the provision of such a method of forming fine filaments including the step of drawing the elements through a die while providing the lubricant material thereto to form the film thereon prior to the bundling step.

A yet further feature of the invention is the provision of such a method of forming fine filaments wherein lubricant material is squeezed transversely outwardly and axially from the sheath during the constricting step.

A further feature of the present invention is the provision of such a method of forming fine filaments wherein lubricant material is squeezed outwardly from the end of the sheath during the constricting step.

Another feature of the present invention is the provision of such a method of forming fine filaments further including the step of removing the lubricant material from the filamentary elements.

Other features and advantages of the invention will be apparent from the following description taken in connection with the accompanying drawing wherein:

FIG. 1 is a schematic block diagram illustrating a method of forming fine filaments embodying the invention;

FIG. 2 is a fragmentary enlarged diagrammatic section of a lubricant applying means thereof;

FIG. 3 is a perspective view of a sheathed bundle of elongated elements illustrating a further step thereof;

FIG. 4 is a diametric section of a constricting die means illustrating a further step thereof;

FIG. 5 is a vertical section of a leaching apparatus illustrating the step of sheath removal thereof;

FIG. 6 is a vertical section of a lubricant removing apparatus illustrating still another step thereof;

FIG. 7 is a diagrammatic vertical section of a modified form of apparatus for applying lubricant material to the wire;

FIG. 8 is a diagrammatic elevation of a modified method of sheathing the bundle by means of a strip cladder; and

FIG. 9 is a diagrammatic elevation illustrating another method of sheathing the bundle by a spiral winding cladder.

In the exemplary embodiment of the invention as disclosed in the drawing, a method of forming fine filaments is shown to comprise the steps of applying a film forming lubricant material **10** to an elongated element, or wire, **11**, bundling a plurality of lengths of the elongated film coated elements in a tubular sheath **12** to define a sheathed bundle **13**, constricting the sheathed bundle **13** to compact the bundle without substantial constriction of the elements **11** therein, drawing of the compacted bundle **13'** to reduce the diameter thereof to a preselected small diameter wherein the wires **11** define fine filaments **14**, removing the sheath **12** in a suitable apparatus generally designated **15**, and removing the lubricant film in a suitable apparatus generally designated **16** to provide the desired fine diameter filaments.

More specifically, the invention comprises forming an ultra-thin, nonmetallic wire supporting means in the bundle **13** permitting the bundle to be constricted, as by cold drawing, without permitting fusion of the individual wires to each other by maintaining the lubricant film therebetween notwithstanding the application of extreme pressure conditions to the film as occur in such drawing processes. By utilization of such ultra-thin separation means, extremely high efficiences in the manufacture of extremely fine diameter filaments are obtained permitting the resultant filament material to compete favorably economically with conventional textile materials.

The invention comprehends the use of different film forming lubricant materials as is discussed more fully hereinafter and is applicable to the forming of such fine filaments from many different drawable materials, such as drawable metals, as is brought out more fully hereinafter. The filaments may be of relatively small diameter and, illustratively may be of extremely small diameter, such as under 12 microns. As will be brought out further hereinafter, different methods of applying the lubricant material to the wire may be employed and different suitable methods of providing the bundle of wires in the surrounding tubular sheath may similarly be utilized. Still further the drawing process may be conducted in conjunction with annealing or heat treating steps or entirely as a cold working process as desired.

More specifically, the invention comprehends utilizing a wire of a commercially available size such as 20 mil diameter wire permitting the constriction thereof to be performed in the most economical region of manufacturing cost so as to provide an end product fine filament at minimum cost. Different wire materials will obviously have optimum cost relationships at different starting diameters and the desired final diameter of the fine filaments similarly affects the desirable starting diameter of the wire. In general, however, the starting wire size providing maximum economy in the manufacture of fine filaments would appear to be in the range of from 10 to 90 mils where the final fine filament diameter is 1 mil or less.

The wire material may be any suitable drawable material and includes a wide range of metals and alloys, such as stainless steel, aluminum, nickel, copper alloys, tantalum, niobium, precious metals, platinum, etc. The wire may be provided as a homogenous wire or may be provided with a surface layer, such as an electrolytically deposited copper plating on an aluminum wire. The stainless steel materials may comprise conventional type 302 and 304 stainless steels and high chromium, high nickel 300 series stainless steels that remain essentially austenitic throughout massive cold reduction. An excellent example of aluminum wire for use in the process is aluminum-1100. An example of nickel wire providing excellent characteristics for use in the process is NI-270.

As indicated above, the lubrication material preferably has a high tenacity characteristic capable of maintaining a film layer on the wires under the extreme conditions occurring in drawing the bundle through the constricting dies. Thus, the term "lubricant" as used herein comprehends organic and inorganic materials having the properties of a high degree of tenacity with coherence and low shear strength or the ability to deform for substantial reductions of section. Illustratively, the film forming lubricant material may comprise a high tenacity oil such as Lubriplate No. 3 swaging oil, greases including silicone greases, silicone lubricants such as General Electric Company's Versilube F-44, soap such as powdered sodium soap, and plastics such as Teflon (tetrafluoroethylene polymer). One method of applying the lubricant material such as soap lubricant material is illustrated in FIG. 2 wherein the wire **11** is drawn through a die **17** while the soap material **10** is applied to the wire. It has been found that such application of the soap to the wire provides a uniform thin coating thereon suitable for providing the desired ultra-thin lubricant film in the constricting steps. Where an excess amount of lubricant material is provided on the wire, it has been found desirable to permit the excess to be squeezed transversely and axially outwardly from the bundle **13** during the constricting steps (see FIG. 4) so as to permit the formation of the ultra-thin film on the individual wires to provide uniformity in the reduced cross-section of the filaments effected by the drawing operation.

Referring to FIG. 7, a modified apparatus for applying the lubricant material to the wire may be seen to comprise a tank **30** containing a body of suitable liquid lubricant through which the wires are longitudinally passed to pick up a coating of the lubricant. Other methods of applying the lubricant will be obvious to those skilled in the art.

The wires **11** may be provided in the form of short length rectilinear wires, as shown in FIG. 3, in the tubular sheath **13** by suitably packing them in parallel relationship therein. Theoretically, the densest possible packing arrangement is one wherein the wires are arrangd in hxagonal array utilizing 91% of the bore of the sheath **13**. It has been found, however, that excellent uniform filaments **18** may be formed wherein slightly less than the optimum packing is effected in the sheath such as for providing ease of handling and preventing crossovers of the wires. To assure desired uniform filament configuration, it is desirable to cause the sheathed bundle of wires **11** to be relatively close packed prior to the drawing operation. This close packing may be effected by slowly drawing the sheathed bundle through a suitable die **31** to constrict the sheath **12** while not substantially constricting the wires **11** therein but rather causing them to approximate a close packed hexagonal configuration in the major portion of the cross-section thereof. An excess of lubricant material on the wires **11** will be squeezed out the end of the sheath at this time to permit the closing down of the voids between the wires to permit the lubricant material to form a thin film on the wires. The removal of the excess lubricant material may also be effected during the initial drawing steps so that ultimately the drawing operation is effected with the lubricant material on the respective wires being present in an ultra-thin layer whereby the cross-section of the composite structure within the sheath is almost 100% wire material. Where the lubricant material is provided on the wires as by application thereto while the wire is drawn through a die, the original film is extremely thin and very little extrusion of the lubricant from the ends of the sheath occurs during the compacting and drawing steps.

Another method of sheathing the bundle of wires **11** is illustrated in FIG. 8 wherein the bundle **19** is embraced by a tubularly folded strip **20** which may be retained in the tubular configuratiton as by the applicatiton of a weld **21** joining the juxtaposed inturned edges of the strip by a suitable conventional welding apparatus **22**. This method of applying the sheath provides the highly desirable feature of permitting a continuous delivery of the sheathed bundle thereby permitting further reduction in the cost of the filament formation.

A still further method of sheathing the bundle **19** of wires is shown in FIG. 9 to comprise a helical wrapping of the bundle by a strip **24** to define a sheath **23** which may be maintained in the helical configuration solely by compacting thereof or by application of suitable weld **25** by the weld apparatus **22** to the juxtaposed edges of the helical turns.

The material of which the sheath is formed is preferably one having a hardness at least equal to the hardness of the wires **11**. It has been found that by maintaining this hardness relationship, the sheath is firstly constricted as it is drawn through the die while the wires more closely arrange themselves in the final generally hexagonal array with the excess lubricant material being forced outwardly from therebetween. The resultant constriction is evenly distributed across the section of the sheathed bundle to provide optimum uniformity in the resultant filaments **18**. One example of such a hardness relationship is that obtained with nickel 270 wires and Monel sheathing. Another example is that obtained with aluminum 1100 wires in a copper tube. While the sheathing material is advantageously as hard or harder than the wire material, the sheathing material should be one having suitable drawing characteristics for facilitated constriction of the sheathed bundle in the subsequent drawing steps. More specifically, where the sheathing material is quite thin, such as occupying less than approximately 10% of the total volume, the hardness thereof may be less than that of the wire material.

As illustrated in FIG. 4, the drawing operation may be conducted in a number of suitable drawing steps. If desired, heat treating of the sheathed bundle between the drawing steps may be effected. Illustratively, the heat treating may comprise annealing. Where such heat treating is utilized, the lubricant material should be one having a high temperature resistant characteristic. Where such heat treatment is used, the lubricant material should further be selected to avoid interaction with the wire material at the elevated temperatures. Illustratively, carbonaceous lubricant materials which would tend to introduce carbon into the outer surface of the wire at elevated temperatures should be avoided where such carbon introduction would adversely affect the wire composititon, such as where the wires are formed of 300 series stainless steel.

The sheath is preferably formed of a material permitting ready separation thereof from the final constricted sheathed bundle **13''**. Illustratively, where the sheath **12** is formed of Monel metal or copper, it may be removed by suitable treatment by nitric acid as illustratively shown in FIG. 5.

The removal of the sheath from the final constricted bundle **13''** results in the provision of the desired filaments **18** which may have a thin film of the lubricant material remaining thereon. Where it is desired to provide the filaments free of this lubricant material, a final lubricant removal step may be utilized. Illustratively, as

shown in FIG. 6, the filaments may be passed through a bath of suitable material to remove the lubricant. Thus, where the lubricant is an oil, the bath **16** may comprise a suitable oil solvent.

Illustratively, where the final constricted bundle **13''** is one wherein the filaments are formed of aluminum or aluminum alloys and the sheathing material is copper, the copper may be removed satisfactorily by use of concentrated, or red fuming, nitric acid which minimizes attack of the aluminum. Alternatively, the copper may be removed by anodic dissolution in a suitable electrolyte.

Examples of filament manufacture in conformity with the above disclosure are as follows:

EXAMPLE 1

0.092 inch diameter aluminum 1100 commercial rivet wire having zero temper was drawn to 0.03 inch diameter through a powdered sodium soap lubricant to provide a residual soap film thereon. 201 of the drawn wires, each 2 feet long, were then inserted into a tubular copper sheath fashioned from conventional ½ inch refrigeration tubing having an approximately 0.625 inch O.D. which had been drawn, without a mandrel, through a .580 inch die on a draw bench. The resulting straight tube had a .580 inch O.D. and approximately .502 inch I.D. The sheath, with the wire bundle contained therein, was then drawn as follows:

(1) 0.562–0.365 inch O.D. by straight drawing on a hydraulic draw bench. Each drawing step was by 10% RA.

(2) 0.344–0.131 inch O.D. by drawing on a medium size bull block with capstan. Each draft was by 10% RA.

(3) 0.121–0.0202 inch O.D. by drawing on a small size bull block with capstan. Again 10% RA drafts were taken.

(4) 0.0191–0.01126 inch O.D. were drawn by hand through 10% RA drafting steps.

(5) 0.01126–0.0063 inch O.D. were drawn by hand through 10% RA drafting steps.

The final bundle **13''** was then treated with 50 volume percent nitric acid to remove the sheath and provide the final filaments **18** having a diameter of 0.0004 inch. The filament material was then subjected to different heat treatments to provide the filaments with different ultimate tensile strengths. Illustratively, the tensile strength of the filaments as drawn were approximately 65,000 p.s.i. for 0.726 mil diameter filaments released from the .01126 inch O.D. composite.

EXAMPLE 2

0.062 inch diameter nickel 270 wire was drawn to 0.04 inch diameter and annealed at 1800° F. 98 lengths of this wire, each 12 inches long, were firstly coated with General Electric Company silicone oil (Versilube type F–44) and wrapped in two turns of commercial 1 mil thick aluminum foil. The bundle of 98 wires was placed in a 0.5 inch O.D. x 0.46 inch I.D. Monel 400 tube which had previously been annealed at 1800° F. The bundle was then drawn down under the following drawing schedule:

(1) 0.460–0.229 inch O.D. (composite) by regular B&S (20% RA) reductions.

(2) 0.229–0.032 inch O.D. by 10% and some 5% RA reductions.

(3) 0.032–0.025 inch O.D. by 20% RA reductions.

(4) All subsequent drawing by 10% RA reductions.

The final sheathed bundle **13'** had an O.D. of 0.0126 inch wherein the filaments had a diameter of 1.11 mils with an ultimate tensile strength of 135,200 p.s.i. as drawn. The filaments were released from the sheathed bundle by treatment with warm nitric acid solution to release the Monel sheathing and then with caustic soda which released the aluminum foil (the aluminum foil serving to protect the nickel against attack by the nitric acid).

EXAMPLE 3

185 lengths of annealed 310 stainless steel having a diameter of 0.012 inch and coated with Versilube silicone oil were placed in a 0.216 inch O.D. x 0.195 inch I.D. Monel 400 tube and the sheathed bundle drawn down through 10% RA decrements to a final sheathed bundle **13'** having an OD of 0.0079 inch wherein the filaments **18** were of 0.504 mil diameter. Filaments of this size showed a strength of 264,000 p.s.i. with a total elongation of 1.40% at 2 inches gage length.

EXAMPLE 4

189 lengths of annealed 7RE12 stainless steel having a diameter of 0.0126 inch were coated with Versilube silicone oil and inserted as a bundle into a tube of Monel 400 metal having a 0.216 O.D. and a 0.195 I.D. The composite was drawn down by 10% RA decrements to a final O.D. of 0.0072 inch wherein the filaments had a diameter of 0.449 mil. The ultimate tensile strength was found to be 133,500 p.s.i. on 2 inch gage length filaments.

While we have described certain embodiments of our invention, it is to be understood that it is capable of many modifications. Changes, therefore, in the disclosed processes embodying the invention may be made without departing from the spirit and scope of the invention as defined in the appended claims.

We claim:

1. A method of forming filaments comprising the steps of: providing a bundle of elongated elements formed of drawable metal arranged coaxially in a tubular sheath formed of a drawable material, said elements having a free metal outer surface; providing on said outer surface of each of said elements a film of lubricant material having a high tenacity characteristic capable of maintaining said film under extreme pressure conditions; constricting said sheathed bundle to reduce the said elements to filamentary diameter while maintaining said film on said outer metal surface whereby said filamentary elements are maintained separate; and removing the sheath.

2. The method of forming filaments as set forth in claim **1** wherein said constricting comprises drawing.

3. The method of forming filaments as set forth in claim **1** wherein said constricting comprises cold drawing.

4. The method of forming filaments as set forth in claim **1** wherein said lubricant material comprises oil.

5. The method of forming filaments as set forth in claim **1** wherein said lubricant material comprises grease.

6. The method of forming filaments as set forth in claim **1** wherein said lubricant material comprises soap.

7. The method of forming filaments as set forth in claim **1** wherein said lubricant material comprises a silicone material.

8. The method of forming filaments as set forth in claim **1** wherein the sheath is formed of a material having a hardness at least equal to the hardness of the elements.

9. The method of forming filaments as set forth in claim **1** wherein said elements comprise metal wire elements having a diameter of under approximately 0.1 inch.

10. The method of forming filaments as set forth in claim **1** wherein said filamentary diameter is under approximately 12 microns.

11. The method of forming filaments as set forth in claim **1** wherein said filaments are formed of a metal alloy.

12. The method of forming filaments as set forth in claim **1** wherein the elements are loosely placed in said sheath and the sheath is drawn down in a first drawing step to compact the element arrangement without substantial constriction of the elements.

13. The method of forming filaments as set forth in claim **1** wherein said lubricant material is provided on the individual elements prior to the provision thereof as a bundle.

14. The method of forming filaments as set forth in claim **1** wherein said lubricant comprises a high temperature resistant material and the constricting comprises a plurality of constricting operations with heat-treating of the constricted sheathed bundle therebetween.

15. The method of forming filaments as set forth in claim **1** further including the step of plating the elongated elements with a metal prior to the bundling thereof.

16. The method of forming filaments as set forth in claim **1** wherein said bundle occupies substantially 91% of the inner cross-section of the sheath prior to the constricting step.

17. A method of forming filaments comprising the steps of: providing a bundle of elongated elements formed of a drawable material arranged coaxially in a tubular sheath formed of a drawable material; providing on each of said elements a film of lubricant material having a high tenacity characteristic capable of maintaining said film under extreme pressure conditions; constricting said sheathed bundle to reduce the said elements to filamentary diameter; and removing the sheath, said elements being formed of aluminum and said lubricant comprising a dry soap film coating.

18. The method of forming filaments as set forth in claim **1** wherein the sheath is formed of a material substantially harder than that of said element.

19. The method of forming filaments as set forth in claim **1** including a step of drawing the elements through a die while providing said lubricant material thereto to form said film thereon.

20. A method of forming filaments comprising the steps of: providing a bundle of elongated elements formed of a drawable material arranged coaxially in a tubular sheath formed of a drawable material; providing on each of said elements a film of lubricant material having a high tenacity characteristic capable of maintaining said film under extreme pressure conditions; constricting said sheathed bundle to reduce the said elements to filamentary diameter; and removing the sheath, said lubricant comprising a plastic.

21. A method of forming filaments comprising the steps of: providing a bundle of elongated elements formed of a drawable material arranged coaxially in a tubular sheath formed of a drawable material; providing on each of said elements a film of lubricant material having a high tenacity characteristic capable of maintaining said film under extreme pressure conditions; constricting said sheathed bundle to reduce the said elements to filamentary diameter; and removing the sheath, said lubricant comprising Teflon.

22. The method of forming filaments as set forth in claim **1** wherein the sheath is provided with an open portion and sufficient lubricant material is provided so that a portion of the lubricant material is squeezed outwardly from said sheath during the constricting step.

23. The method of forming filaments as set forth in claim **1** wherein the sheath is provided with an open portion and sufficient lubricant material is provided so that a portion of the lubricant material is squeezed outwardly from said end of said sheath during the constricting step.

24. The method of forming filaments as set forth in claim **1** further including the step of removing said lubricant material from the filamentary elements.

25. The method of forming filaments of claim **1** wherein the volume ratio of the lubricant material to the elongated element material is less than 10 percent.

26. A method of forming filaments comprising the steps of: providing a bundle of elongated elements formed of a drawable material arranged coaxially in a tubular sheath formed of a drawable material; providing on each of said elements a film of lubricant material having a high tenacity characteristic capable of maintaining said film under extreme pressure conditions; constricting said sheathed bundle to reduce the said elements to filamentary diameter; and removing the sheath, said elongated elements being formed of aluminum.

27. The method of forming filaments of claim **1** wherein said film is formed on the elongated elements from a powdered material.

28. The method of forming filaments of claim 1 wherein said lubricant material comprises a material having the properties of a high degree of tenacity with coherence and low shear strength.

29. The method of forming filaments of claim 1 wherein said lubricant material comprises a material having the ability to deform for substantial reductions of section.

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