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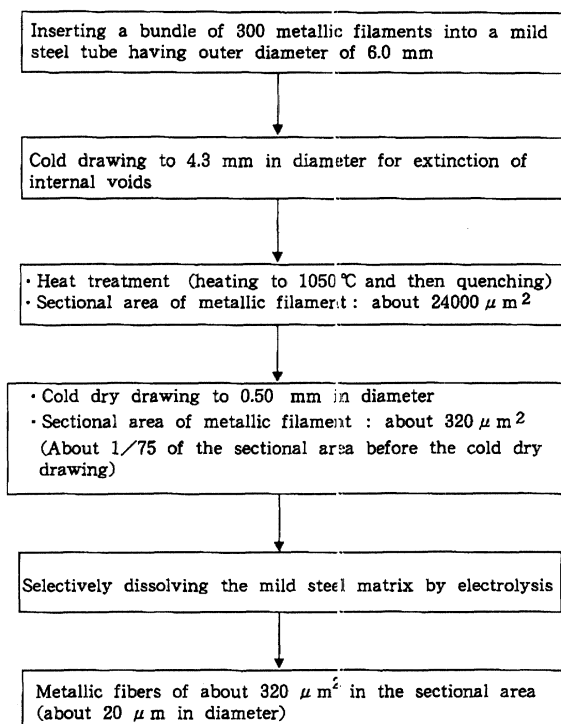
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(54) **Method of bundle-drawing and method for producing metallic fibers**

(57) A method of bundle-drawing comprising a step of reduction in sectional area of a composite wire into a predetermined size is disclosed. The composite wire is comprised of metallic filaments continuous in longitudinal direction and a matrix of metallic material different from that of said metallic filaments and containing the metallic filaments. The composite wire in which section-

al area of the metallic filaments in the composite wire is reduced into not more than 1/35 of their original sectional area without intermediate heat treatment. A method for producing metallic fibers applying the above method is also disclosed. Hard metallic fibers of good accuracy in size and less degradation in property can be produced by less processing steps. Metallic fibers remarkably strengthened by work hardening can be produced.

Fig.1



Description

[0001] The present invention relates to a method of bundle-drawing in which a composite wire, containing a plurality of metallic filaments continuous in longitudinal direction and embedded in a matrix, is reduced in sectional area into a predetermined size, and a method for producing metallic fibers applying a method of bundle-drawing. Particularly, the present invention relates to a method for producing fine metallic fibers having sectional area not more than $700 \mu\text{m}$ (not more than about $30 \mu\text{m}$ in equivalent diameter) by reduction in sectional area of a composite wire containing a plurality of metallic filaments continuous in longitudinal direction and embedded in a matrix into a predetermined size and removal of the matrix.

[0002] Bundle-drawing, in which a composite wire, containing a plurality of metallic filaments continuous in longitudinal direction and embedded in a matrix, is reduced in sectional area into a predetermined size, is used for production of such products as structural composite wires, super-conductive wires and fine metallic fibers. Particularly, fine metallic fibers are used as a material of such products as filter media, anti-static materials and electromagnetic insulators, owing to their good processability for making felts, threads, textiles and the like.

[0003] Fine metallic fibers can be produced by single-wire-drawing in which a single material wire is progressively reduced until the sectional area reaches a desired size. But this method is very low in productivity. Therefore, bundle-drawing, in which a plurality of metallic filaments are simultaneously reduced in sectional area, is widely applied.

[0004] In a method of producing metallic fibers applying bundle-drawing, a composite wire, which contains a plurality of metallic filaments continuously embedded in a matrix to the longitudinal direction, is firstly prepared. For example, one of following methods can be applied for forming a composite wire.

(1) A method in which a bundle of metallic filaments having a cladding layer or a plating on the surface is inserted into a tubular armor, and then tightened. In this case, a composite wire wherein the cladding layer or plating and the tubular armor correspond to a matrix can be obtained.

(2) A method in which a metallic matrix is bored to make many holes extending in the longitudinal direction of the metallic matrix, and then a metallic filament is inserted in each of the holes.

[0005] The composite wire formed by such method is reduced in sectional area to obtain a composite filament containing many metallic filaments having desired sectional area. Further, the matrix of the composite filament is selectively removed to obtain a bundle of metallic fibers.

[0006] As a means for reducing a composite wire in sectional area, hot extrusion, hot rolling, cold drawing and the like are generally used.

[0007] As a means for selective removal of the matrix, dissolution in acid solution or electrolysis is used. It is advantageous for selective removal of the matrix to use a material having higher corrosion resistance as a material of metallic fibers. For example, stainless steels, nickel or nickel alloys, titanium or titanium alloys and the like are advantageously used.

[0008] More concretely, such techniques as follows are disclosed.

[0009] In a process disclosed in JP-A 47-22856, a set of lead patenting and cold drawing is repeatedly applied 6 times on a composite wire formed by covering a bundle of 300 stainless steel filaments of 0.1 mm in diameter having copper plating previously formed on the surface with an armor of middle carbon steel, and then the armor and the copper plating is removed to obtain metallic fibers of $7 \mu\text{m}$ in diameter. The flow chart of this process is shown in Fig.6.

[0010] In a process disclosed in JP-A 47-26367 as an example using extremely ductile components, 97 nickel filaments each having an aluminum cladding layer on the surface are inserted into an aluminum tube of 15.9 mm in outer diameter and 14.1 mm in inner diameter to form a composite wire, then the composite wire is reduced to 0.72 mm in diameter by cold drawing, and then two sets of stress relieving heat treatment and cold drawing are applied on the composite wire to form a composite filament of 0.18 mm in diameter, and after that, the matrix of aluminum is dissolved to obtain metallic fibers of $13 \mu\text{m}$ in diameter.

[0011] Further, in a process disclosed in JP-A 62-259612, 200 stainless steel filaments covered with carbon steel are placed parallel with each other in a carbon steel tube, and hot rolling is applied thereon to form a composite wire of 5.5 mm in diameter, and then the composite wire is reduced to 1.0 mm in diameter by one stage of cold drawing, and after that, the matrix of carbon steel is dissolved in an acid solution to obtain metallic fibers of about $20 \mu\text{m}$ in diameter. The flow chart of this process is shown in Fig.7.

[0012] Though a method of producing metallic fibers applying bundle-drawing is higher in productivity than that applying single-wire-drawing alone, processing with large reduction is necessary in any case. For example, in case of producing metallic fibers of not more than $700 \mu\text{m}^2$ in diameter using a metallic wire of 5.5 mm in diameter as a starting material, the total reduction in sectional area, which is sum of reductions by single-wire-drawing and bundle-drawing, is equivalent to a reduction in which sectional area is reduced to about $1/34000$ of its original value. Therefore, when the reduction is performed by cold drawing, it is necessary to insert many heat treatments on the way of cold drawing. In addition, in order to produce metallic fibers applying bundle-drawing with high efficiency, it is preferable to

increase ratio of reduction applied on a composite wire to the total reduction, thereby increasing number of heat treatment on the composite wire. For example, the number of heat treatment in the method disclosed in JP-A 47-22356 is six times and two times in JP-A 47-26367, and reduction in sectional area by final cold drawing is small in both method.

[0013] Therefore, there are following problems in methods for producing metallic fibers applying bundle-drawing according to prior arts

- (1) Many steps are necessary because many heat treatments should be inserted on the way of reduction.
- (2) Sectional area of metallic filaments contained in the composite wire is very small when heat treatment is performed on the composite wire before final cold drawing, causing such problems as degradation of corrosion resistance and decrease in yield of metallic fibers obtained after removal of the matrix, due to effect of diffusion between the matrix and the metallic filaments.
- (3) Metallic fibers of high strength cannot be obtained because degree of work hardening is small due to small reduction in final cold drawing.

[0014] On the other hand, in a process disclosed in JP-A 62-259612, hot rolling is applied and one step of cold drawing is applied only for final drawing, attempting decrease in number of steps. However, the amount of reduction by the cold drawing is as small as that makes sectional area of the metallic filaments reduced to 1/30. Therefore, it is necessary for production of metallic fibers of smaller diameter to add further heat treatment and cold drawing or to decrease in sectional area of the metallic filaments before cold drawing by increase in amount of hot rolling. And the problems (1) to(3) mentioned above has not been fundamentally solved.

[0015] Therefore, an objective of the present invention is to provide a method of bundle-drawing by which a composite wire containing metallic filaments having good accuracy in size and no degradation in property is produced and a method for producing metallic fibers by which metallic fibers highly strengthened by work hardening are produced.

[0016] The inventors devoted themselves to solving the above problems of prior arts and found followings and achieved the invention.

- (1) Composite wires even containing hard metal, such as stainless steel or industrial titanium alloys, as the metallic filaments can be reduced in sectional area by cold drawing with large reduction that makes the sectional area of the metallic filaments not more than 1/35 of their original sectional area without intermediate heat treatment inserted into the way of the cold drawing. And problems of prior arts can be solved by application of cold drawing

with such a large reduction

- (2) There exists a preferred condition for cold drawing with such a large reduction.

5 **[0017]** A method of bundle-drawing according to the invention comprises a step of reduction in sectional area of a composite wire into a predetermined size, the composite wire being comprised of a plurality of metallic filaments continuous in longitudinal direction and a matrix made of metallic material different from that of said metallic filaments, wherein said metallic filaments are made of hard metallic material, and said step of reduction in area of a composite wire comprises a cold drawing of said composite wire in which sectional area of the metallic filaments in said composite wire is reduced into not more than 1/35 of their original sectional area without intermediate heat treatment.

10 **[0018]** In the above method of bundle-drawing, hard metallic material used for the metallic filament is defined as metallic material having Vickers hardness of not less than 100 when it is heat treated with standard condition.

15 **[0019]** Another method for producing metallic fibers comprises a step of making a composite filament containing a plurality of steel filaments each having sectional area not more than $700 \mu m^2$ (not more than $30 \mu m$ in equivalent diameter) by reduction in sectional area of a composite wire being comprised of a plurality of metallic filaments continuous in longitudinal direction and a matrix made of metallic material different from that of said metallic filaments, and a step of obtaining metallic fibers by removing the matrix of said composite filament, wherein, in the step of making a composite filament, at least the final stage of reduction in sectional area of said composite wire is performed by cold drawing in which sectional area of the metallic filaments in said composite wire is reduced into not more than 1/35 of their original sectional area without intermediate heat treatment, and no heat treatment is applied on the composite wire or the composite filament; when the sectional area of the metallic filaments contained in the composite wire or the composite filament has become less than $2000 \mu m^2$ (less than about $50 \mu m$ in equivalent diameter).

20 **[0020]** The method for producing metallic fibers according to the present invention is suitable for production of very fine metallic filaments having sectional area of not more than $80 \mu m^2$ (not more than $10 \mu m$ in equivalent diameter). And very fine metallic filaments of high quality can be produced with less steps owing to applying cold processing with large reduction which makes sectional area of each metallic in a composite wire not more than $80 \mu m^2$.

25 **[0021]** In a method for producing metallic fibers according to the present invention, it is preferable that the composite wire has no internal voids when the composite wire is provided for the cold drawing which makes the sectional area of the metallic filaments in the composite wire not more than 1/35 without intermediate heat treatment. Further, it is preferable that the cold drawing

which makes the sectional area of metallic filaments in a composite wire not more than 1/35 without intermediate heat treatment is applied on a composite wire which has been heat treated or hot processed and contains metallic filaments each having sectional area of not less than $2000 \mu m^2$.

[0022] Furthermore, it is preferable that the ratio of matrix in a composite wire for the processing is not more than 60vol%.

[0023] Another method for producing metallic fibers according to the present invention is characterized by that a composite filament having predetermined size is produced by a bundle-drawing according to the present invention and the matrix is removed by dissolution to obtain metallic fibers. In this process, it is particularly preferable to use ferrous alloys containing chromium of not less than 10wt% or industrial titanium alloys as the metallic filaments, and mild steel as the matrix.

Brief Description of Drawings

[0024] Fig.1 is a flow chart of a method for producing metallic fibers according to the Example 1.

[0025] Fig.2 is a flow chart of a method for producing metallic fibers according to the Example 2.

[0026] Fig.3 is a flow chart of a method of bundle-drawing and a method for producing metallic fibers according to the Example 3.

[0027] Fig.4 is a flow chart of a method for producing metallic fibers according to the Example 4.

[0028] Fig.5 is a flow chart of a method for producing metallic fibers according to the Comparative example.

[0029] Fig.6 is a flow chart of a method of bundle-drawing and a method for producing metallic fibers according to a prior art.

[0030] Fig.7 is a flow chart of a method of bundle-drawing and a method for producing metallic fibers according to another prior art.

[0031] The present invention will be explained in detail as follows.

[0032] One method of bundle-drawing according to the present invention is intended to process a composite wire containing hard metallic filaments which has not been processed by cold working with large reduction in conventional methods. A hard metallic filament is defined as a filament made of metallic material having Vickers hardness of not less than 100 when it is treated by standard heat treatment. Examples of such material are ferrous alloys such as stainless steels, heat resisting steels or non magnetic steels, nickel alloys such as Monel, Inconel or Hastelloy, or industrial titanium alloys as α titanium alloys, β titanium alloys, α / β titanium alloys or pure titanium of JIS2 and JIS3.

[0033] The method of bundle-drawing according to the present invention is characterized by that a composite wire containing hard metallic filaments described above is reduced by a cold drawing with large reduction and without intermediate heat treatment which makes

the sectional area of the metallic filaments in the composite wire not more than 1/35, preferably not more than 1/55, more preferably 1/90-1/3000, of the original diameter. By this method, a composite filament containing metallic filaments of good accuracy in size and no degradation in property can be produced with less steps.

[0034] Another method for producing metallic fibers according to the present invention is characterized by that at least the final step of reduction of a composite wire to make a composite filament is performed by a cold drawing with large reduction and without intermediate heat treatment which makes the sectional area of the metallic filaments in the composite wire not more than 1/35, preferably not more than 1/55, more preferably 1/90-1/3000, of the original diameter, and that no heat treatment is applied on a composite wire or a composite filament when the sectional area of each metallic filament has become less than $2000 \mu m^2$. The objective of above cold drawing with large reduction and without intermediate heat treatment are to decrease number of processing steps and to achieve higher strength of metallic fibers.

[0035] As a means for cold drawing with large reduction to make the sectional area of metallic filaments in a composite wire not more than 1/35, drawing with hole dies, drawing with roller (lies or cold rolling can be applied). However, it is preferable to use drawing with hole dies which is advantageous in uniform deformation and accuracy in size. Particularly, in this case, it is preferable to select approach angle of dies and reduction per die considering uniformity of deformation in first priority, needless to say proper setting of drawing conditions such as lubrication and pass schedule to perform successful cold drawing with hole dies. More concretely, in case of using hole dies having approach angle of 8 to 12 degrees, it is preferable to set average reduction per die not less than 20% at least in the first half of the cold drawing.

[0036] The cold drawing with large reduction in the present invention is not always performed by one stage of continuous drawing and can be divided into plural stages of continuous drawing. For example, the cold drawing can be divided into a stage of continuous dry drawing as the first half and continuous wet drawing as the last half. It is important to keep good lubrication during the cold drawing with large reduction, and, if necessary, formation of a lubricating film may be inserted in the way of cold drawing. As a lubricating film for continuous dry drawing, for example, borax film can be applied. And in this case, it is preferable to form a uniformly thick film of about $4-7g/mm^2$. This treatment enables cold drawing with large reduction even in one stage by one treatment for forming a lubricating film. And it is preferable to perform continuous wet drawing after formation of copper plating, brass plating and the like.

[0037] In one method for producing metallic fibers according to the invention, the reason why no heat treatment is performed on a composite wire or composite fil-

ament when the sectional area of the metallic filaments has become less than $2000 \mu m^2$ is that, if a heat treatment or hot working is performed on a composite wire containing metallic filaments of less than $2000 \mu m^2$ in sectional area, it apt to cause such problems as decrease in yield of metallic fibers obtained after removal of the matrix due to remarkable effect of diffusion between the matrix and the metallic filaments. Preferably, by setting the sectional area of metallic filaments in the composite wire not less than $5000 \mu m^2$, the effect of diffusion by heating between the matrix and the metallic filaments can be made negligibly small when a heat treatment or hot working is performed on the composite wire.

[0038] Further, limitation in heat treatment condition on a composite wire can be largely relaxed by setting the sectional area of metallic filaments in the composite wire not less than $2000 \mu m^2$, preferably not less than $5000 \mu m^2$ (not less than $80 \mu m$ in equivalent diameter) when heat treatment or hot working is performed on the composite wire. For example, though standard solution heat treatment temperature for austenitic stainless steel is $1000^\circ C$ - $1100^\circ C$, in case of producing fine metallic fibers by applying a plurality of heat treatment and cold drawing on a composite wire containing austenitic stainless steel filaments, it is necessary to limit temperature in each heat treatment to less than about $950^\circ C$ to control the effect of diffusion between the matrix and the metallic filaments, considering total heat quantity of the heat treatments and the sectional area of the metallic filaments on and after the second heat treatment. On the other hand, in case of that a heat treatment is performed on a composite wire containing austenite stainless steel filaments of not less than $2000 \mu m^2$, preferably not less than $5000 \mu m^2$, and no heat treatment is inserted in the way of reduction thereafter, there is no problem of diffusion between the matrix and the metallic filaments even when the heat treatment temperature is $1000^\circ C$ - $1100^\circ C$. Therefore, corrosion resistance of cold worked austenitic stainless steel is not degraded and good processability in cold drawing with large reduction is also achieved.

[0039] Preferably, a composite wire provided for the cold drawing with large reduction in the present invention has a construction which enables the metallic filaments and the matrix processed like one body, considering uniform distribution of deformation.

[0040] Preferable construction of a composite wire is as follows;

- (1) Metallic filaments are disposed continuously to the longitudinal direction of a composite wire.
- (2) Metallic filaments are disposed substantially parallel to the longitudinal direction of a composite wire.
- (3) Metallic filaments are distributed in the cross section of a composite wire nearly uniformly and axially symmetrically.

(4) Ratio of matrix in a composite wire is preferably not more than 60vol%, more preferably not more than 50vol%.

(5) There exist no voids within a composite wire.

If ratio of matrix is too high and the thickness of the matrix of different material between metallic filaments is increased, necking deformation of the metallic filaments is apt to occur due to uneven deformation. Further, in case of applying the bundle-drawing for production of metallic fibers, ratio of matrix is preferably set not less than 10vol%, more preferably not less than 20vol% in order to facilitate separation of metallic fibers by dissolution of the matrix. Further, if there exist some voids within a composite wire, efficiency of reduction is decreased because part of the reduction is spent for extinction of the voids. In case of forming a composite wire by inserting a bundle of metallic filaments into a tubular armor, there can be some voids within the composite wire. In this case, the voids can be become disappeared by hot working, slight cold drawing and the like. When the voids are made disappeared by slight cold drawing, it is preferable to apply heat treatment before cold drawing with large reduction in order to decrease in strain induced by the slight cold drawing for extinction of the voids.

[0041] In this case, the sectional area of metallic filaments is also set not less than $2000 \mu m^2$, preferably not less than $5000 \mu m^2$ when heat treatment or hot working is performed on the composite wire.

[0042] In a method for producing metallic fibers according to the present invention, it is preferable to select material of the matrix more easily dissolved by dissolution in acid or electrolysis than the material of the metallic filaments in order to obtain metallic fibers by removal of the matrix in a composite filament. For example, mild steel is preferable for the material of the matrix for production of metallic fibers when the material of the metallic filament is ferrous alloys such as stainless steels containing chromium of not less than 10wt% or heat resisting steels, pure titanium, industrial titanium alloys, nickel or nickel alloys. A mild steel containing less than 0.12wt% of carbon is more preferable and metallic fibers of good quality can be obtained without effect of diffusion of carbon from the matrix.

[0043] As a means for selective dissolution of the matrix, dissolution in nitric acid solution, selective dissolution by electrolysis and the like can be applied. In particular, in case of using mild steel as matrix, the matrix can be selectively dissolved by electrolysis using sulfuric acid solution as a electrolytic solution. This means is advantageous in view of safety or working environment.

[0044] A method for producing metallic fibers according to the invention is particularly suitable for production of very fine metallic fibers having sectional area of not more than $80 \mu m^2$ (not more than about $10 \mu m$ in equivalent diameter), especially not more than $20 \mu m^2$ (not

more than about 5 μ m in equivalent diameter). And very fine metallic fibers of high quality can be produced by considerably decreased number of processing steps. In case of applying the invention for production of very fine metallic fibers having sectional area of not more than 20 μ m² (not more than about 5 μ m in equivalent diameter), no heat treatment or hot working is performed on a composite wire when the sectional area of each metallic filament has become less than 2000 μ m², and last stage of reduction should be performed by cold drawing with very large reduction in which the sectional area of the metallic filaments in the composite wire is reduced to not more than 1/100. However, the process can be performed successfully by proper application of the preferable conditions described above.

[0045] Conventionally, for production of very fine metallic fibers having sectional area of not more than 80 μ m² (not more than about 10 μ m in equivalent diameter), there is a method in which a plurality of composite wire is bundled after reduction in some degree to form a double-composite wire, and then, the double-composite wire is further reduced. However, this method is not preferable because the number of processing step is rather increased. When a method of producing metallic fibers according to the invention is applied for production of very fine metallic fibers, it is preferable to increase the reduction of cold drawing in the last stage, reducing the size to a predetermined value without formation of a double composite wire.

[0046] As explained above, in a method for producing metallic fibers according to the invention, a composite wire containing hard metallic filaments of good size accuracy and no degradation in property can be produced with less number of processing steps, because at least the last stage of reduction is performed by cold drawing with large reduction in which the sectional area of the metallic filament in the composite wire is reduced to not more than 1/35 of its original value without intermediate heat treatment, and in particular, no heat treatment is applied on the composite wire or composite filament when the sectional area of each metallic filament has become less than 2000 μ m². This effect is particularly remarkable in case of production of very fine metallic fibers which conventionally needs great many processing steps, and the number of processing steps necessary for the production can be remarkably decreased.

[0047] Further, by a method for producing metallic fibers according to the invention, hard metallic fibers of good accuracy in size and less degradation in property can be produced by less processing steps.

[0048] Furthermore, by applying cold drawing with large reduction for the last stage of reduction, metallic fibers remarkably strengthened by work hardening can be produced.

[0049] Following is explanation of the present invention with some examples. However, the present invention should not be limited within the examples.

Example 1

[0050] A cladding of mild steel was formed on the surface of a austenitic stainless steel wire containing about 18wt% of chromium and about 8wt% of nickel, and, by heat treatment and cold drawing, metallic filaments having mild steel cladding of 18 μ m in thickness and outer diameter of 0.23mm were formed. And a composite wire was formed by inserting a bundle of 300 metallic filaments into a mild steel tube having outer diameter of 6.0mm and thickness of 0.4mm.

[0051] Then, after cold drawing with roller dies to 4.3mm in outer diameter for extinction of internal voids, the composite wire was applied to a heat treatment of heating to about 1050°C and quenching. At this point, the sectional area of each metallic filament was about 24000 μ m² (about 175 μ m in equivalent diameter), and ratio of matrix was about 50vol%. And Vickers hardness of the metallic fiber was about 160

[0052] The composite wire was reduced to 0.50mm in diameter by cold dry drawing with 15 dies using a multi head dry drawing machine without intermediate heat treatment. The sectional area of each metallic filament in this composite wire was about 320 μ m² (about 20 μ m in equivalent diameter) and was about 1/75 of the sectional area before the cold dry drawing. In the cold dry drawing, uniform deformation was intended by using hole dies having approach angle of about 10 degree and setting average reduction per die about 25%. The cold dry drawing was performed after forming borax film of about 5g/m² to obtain good lubrication. As the result, no wire breakage was occurred during the cold dry drawing.

[0053] Then, the matrix (the part corresponding to mild steel cladding and mild steel tube) was selectively dissolved by electrolysis in sulfuric acid solution, and a bundle of stainless steel fibers of about 20 μ m in diameter was obtained. The stainless steel fibers were continuous in the longitudinal direction and had good accuracy in size with no necking and no degradation in property by diffusion of the matrix was observed. The process of this Example 1 is shown in Fig.1.

Example 2

[0054] A cladding of mild steel was formed on the surface of a nickel wire, and, by heat treatment and cold drawing, metallic filaments having mild steel cladding of about 15 μ m in thickness and outer diameter of 0.20mm were formed. And a composite wire was formed by inserting a bundle of 400 metallic filaments into a mild steel tube having outer diameter of 6.0mm and thickness of 0.4mm.

[0055] Then, after cold drawing with roller dies to 4.3mm in outer diameter for extinction of internal voids, the composite wire was applied to a annealing heat treatment at about 900°C. At. this point, the sectional area of each metallic filament was about 21000 μ m²

(about 165 μ m in equivalent diameter), and ratio of matrix was about 40vol%.

[0056] The composite wire was reduced to 0.39mm in diameter by cold dry drawing with 17 dies (average reduction per die being 25%) using a multi head dry drawing machine without intermediate heat treatment. The sectional area of each metallic filament in this composite wire was about 180 μ m² (about 15 μ m in equivalent diameter) and was about 1/120 of the sectional area before the cold dry drawing. The cold dry drawing was performed in same condition as Example 1 using hole dies having approach angle of about 10 degree after forming borax film of about 5g/m² to obtain good lubrication. As the result, no wire breakage was occurred during the cold dry drawing.

[0057] Then, the matrix (the part corresponding to mild steel cladding and mild steel tube) was selectively dissolved by electrolysis in sulfuric acid solution and a bundle of nickel fibers of about 15 μ m in diameter was obtained. The nickel fibers were continuous in the longitudinal direction and had good accuracy in size with no necking and no degradation in property by diffusion of the matrix was observed. The process of this Example 2 is shown in Fig.2.

Example 3

[0058] A composite billet, comprising austenitic stainless steel wires containing about 16wt% of chromium, about 10wt% of nickel and about 2wt% of molybdenum embedded in a mild steel matrix, was hot rolled to prepare a composite wire of 5.5mm in diameter. The composite wire contained 1700 metallic filaments disposed continuously and substantially parallel to the longitudinal direction of the composite wire. Sectional area of each metallic filament was about 5700 μ m², and Vickers hardness of each metallic filament was about 190. And ratio of the matrix in the composite wire was about 59vol%.

[0059] The composite wire was reduced to 0.52mm in diameter by cold dry drawing with 17 dies (average reduction per die being 25%) using a multi head dry drawing machine without intermediate heat treatment. The sectional area of each metallic filaments in this composite wire was about 50 μ m² (about 8 μ m in equivalent diameter) and was about 1/114 of the sectional area before the cold dry drawing. The cold dry drawing was performed in same condition as Example 1 using hole dies having approach angle of about 10 degree after forming borax film of about 5g/m² to obtain good lubrication. As the result, no wire breakage was occurred during the cold dry drawing.

[0060] Further, copper plating was formed on the composite wire of 0.52mm in diameter. Then, the composite wire was reduced to 0.13mm in diameter by cold wet drawing with 13 dies using a multi head wet drawing machine without intermediate heat treatment. The sectional area of each metallic filament in this composite

wire was about 3 μ m² (about 2 μ m in equivalent diameter) and was about 1/1800 of the sectional area before the cold dry drawing and the cold wet drawing. The cold wet drawing was performed using hole dies having approach angle of about 10 degrees, and reduction per die was set not less than 20% at some dies successively arranged in the first half of the cold wet drawing to obtain uniform deformation. As the result, no wire breakage was occurred during the cold wet drawing.

[0061] Then, the mild steel matrix was selectively dissolved by electrolysis in sulfuric acid solution, and a bundle of metallic fibers of about 2 μ m in diameter was obtained. The metallic fibers were continuous in the longitudinal direction, and no degradation in property by diffusion of the matrix was observed. The process of this Example 3 is shown in Fig.3.

Example 4

[0062] A composite billet, comprising austenitic stainless steel wires containing about 16wt% of chromium, about 10wt% of nickel and about 2wt% of molybdenum embedded in a mild steel matrix, was hot rolled to prepare a composite wire of 5.5mm in diameter. The composite wire contained 1700 metallic filaments disposed continuously and substantially parallel to the longitudinal direction of the composite wire. Sectional area of each metallic filament was about 5700 μ m², and Vickers hardness of each metallic filament was about 190. And ratio of the matrix in the composite wire was about 59vol%.

[0063] The composite wire was reduced to 1.5mm in diameter by cold dry drawing with 9 dies (average reduction per die being 25%) using a multi head dry drawing machine without intermediate heat treatment. The sectional area of each metallic filaments in this composite wire was about 420 μ m² (about 23 μ m in equivalent diameter). The cold dry drawing was performed in same condition as Example 1 and 2 using hole dies having approach angle of about 10 degree after forming borax film of about 5g/m². As the result, no wire breakage was occurred during the cold dry drawing.

[0064] Further, copper plating was formed on the composite wire of 1.5mm in diameter without heat treatment before formation of the copper plating. Then, the composite wire was reduced to 0.13mm in diameter by cold wet drawing with 25 dies using a multi head wet drawing machine without intermediate heat treatment. The sectional area of each metallic filament in this composite wire was about 3 μ m² (about 2 μ m in equivalent diameter) and was about 1/1800 of the sectional area before the cold dry drawing and the cold wet drawing. The cold wet drawing was performed using hole dies having approach angle of about 10 degrees, and reduction per die was set not less than 20% at some dies successively arranged in the first half of the cold wet drawing to obtain uniform deformation. As the result, no wire breakage was occurred during the cold wet drawing.

[0065] Then, the mild steel matrix was selectively dissolved by electrolysis in sulfuric acid solution, and a bundle of metallic fibers of about 2 μm in diameter was obtained. The metallic fibers were continuous in the longitudinal direction, and no degradation in property by diffusion of the matrix was observed. The process of this Example 4 is shown in Fig.4.

Comparative example

[0066] A composite wire of 1.5mm in diameter produced by the same process as in Example 4 was applied to a heat treatment of heating to about 1050°C and quenching. At this point, sectional area of each metallic filament in the composite wire was about 420 μm^2 (about 23 μm in equivalent diameter).

[0067] Then, copper plating was formed on the composite wire. And the composite wire was reduced to produce a composite filament of 0.13mm in diameter by cold wet drawing with the same condition as Example 4. However, wire breakage was frequently occurred during the cold wet drawing.

[0068] Further, selective removal of the mild steel matrix was tried by electrolysis in sulfuric acid solution. But the bundle of stainless steel fibers could not be separated completely even after electrolysis for about 1 hour. The process of this Comparative example is shown in Fig.5.

Claims

1. A method of bundle-drawing comprising a step of reduction in sectional area of a composite wire into a predetermined size, the composite wire being comprised of a plurality of metallic filaments continuous in longitudinal direction and a matrix made of metallic material different from that of said metallic filaments and containing said metallic filaments, wherein said metallic filaments are made of hard metallic material, and said step of reduction in area of a composite wire comprises a cold drawing of said composite wire in which sectional area of the metallic filaments in said composite wire is reduced into not more than 1/35 of their original sectional area without intermediate heat treatment inserted on the way of the cold drawing.
2. A method of bundle-drawing according to claim 1, wherein Vickers hardness of said metallic filaments is not less than 100.
3. A method of bundle drawing according to claim 1, wherein said cold drawing is performed on a composite wire having no voids therein.
4. A method of bundle drawing according to claim 1, wherein said cold drawing is performed on a com-

posite wire on which hot working or heat treatment has been applied and which contains metallic filaments each having sectional area not less than 2000 μm^2 .

5. A method of bundle drawing according to claim 1, wherein ratio of matrix in the composite wire is not more than 60% in volume.
6. A method for producing metallic fiber comprising a step of making a composite filament containing a plurality of steel filaments each having sectional area not more than 700 μm^2 by reduction in sectional area of a composite wire being comprised of a plurality of metallic filaments continuous in longitudinal direction and a matrix made of metallic material different from that of said metallic filaments, and a step of obtaining metallic fibers by removing the matrix of said composite filament, wherein, in the step of making a composite filament, at least the final stage of reduction in sectional area of said composite wire is performed by cold drawing in which sectional area of the metallic filaments in said composite wire is reduced into not more than 1/35 of their original sectional area without intermediate heat treatment inserted on the way of the cold drawing, and no heat treatment is applied on the composite wire or the composite filament when the sectional area of the metallic filaments contained in the composite wire or the composite filament has become not more than 2000 μm^2 .
7. A method for producing metallic fibers according to claim 6, wherein sectional area of each metallic filament contained in said composite filament is not more than 80 μm^2 .
8. A method for producing metallic fiber according to claim 6, wherein said cold drawing is performed on a composite wire having no voids therein.
9. A method for producing metallic fiber according to claim 6, wherein said cold drawing is performed on a composite wire on which hot working or heat treatment has been applied and which contains metallic filaments each having sectional area not less than 2000 μm^2 .
10. A method for producing metallic fiber according to claim 6, wherein ratio of matrix in the composite wire is not more than 60% in volume.
11. A method for producing metallic fibers comprising a step of making a composite wire having predetermined size by a method of bundle drawing according to any of claims 1 to 5, and a step of removal of the matrix of the composite wire to obtain metallic fibers.

12. A method for producing metallic fibers according to claim 11, wherein the metallic filaments are made of a ferrous alloy containing chromium not less than 10% in weight or a industrial titanium alloy, and the matrix is made of mild steel.

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Fig.1

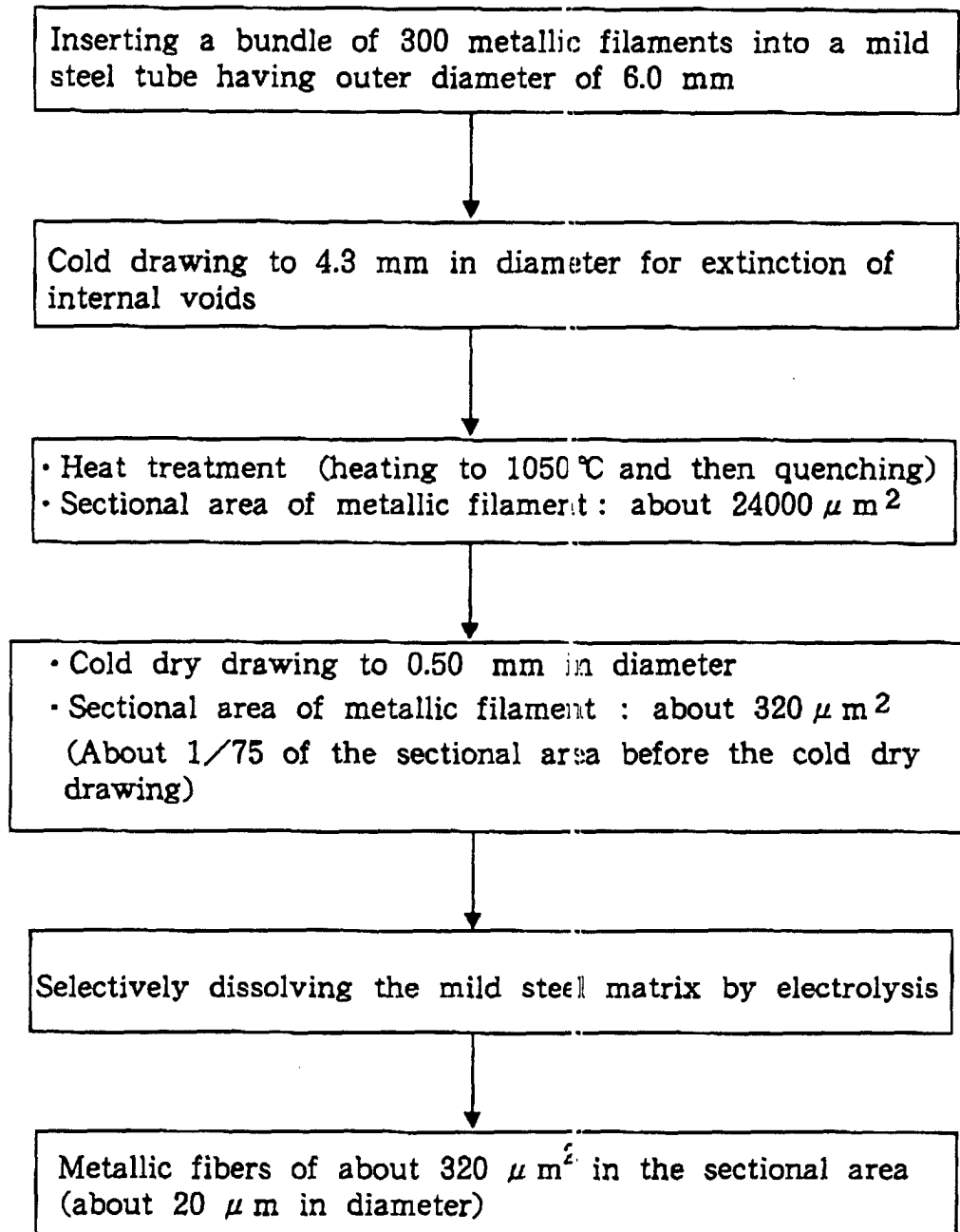


Fig.2

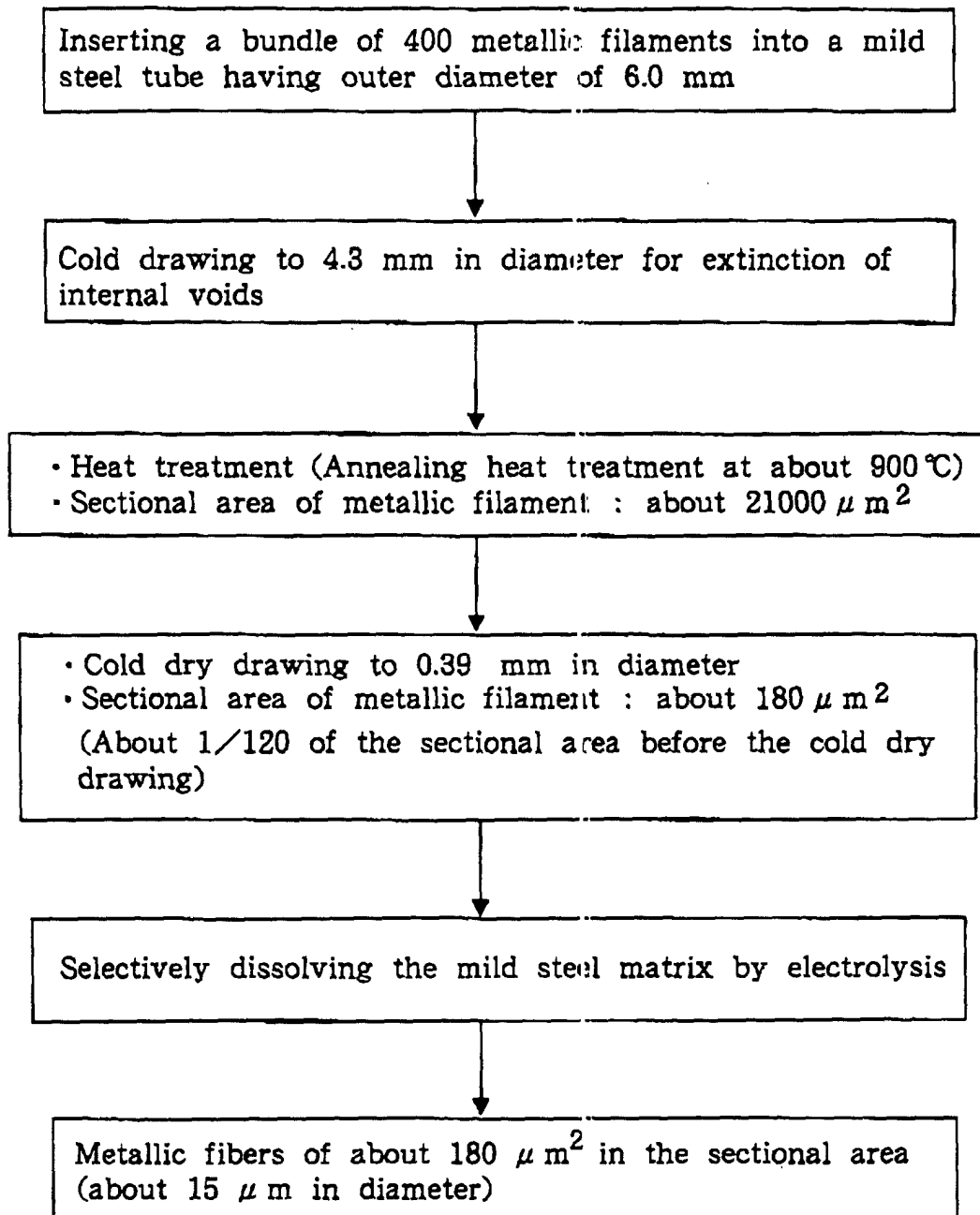


Fig.3

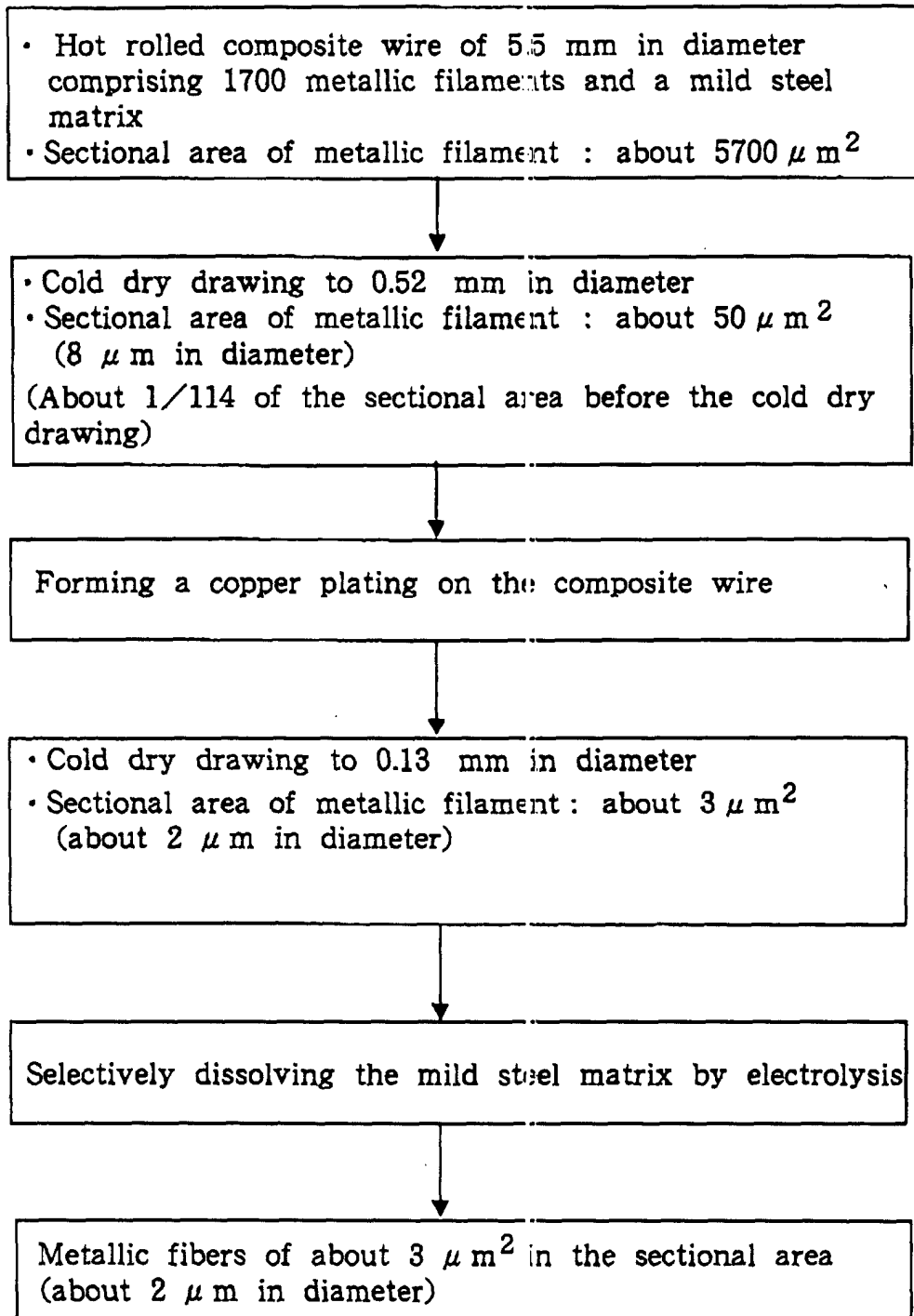


Fig.4

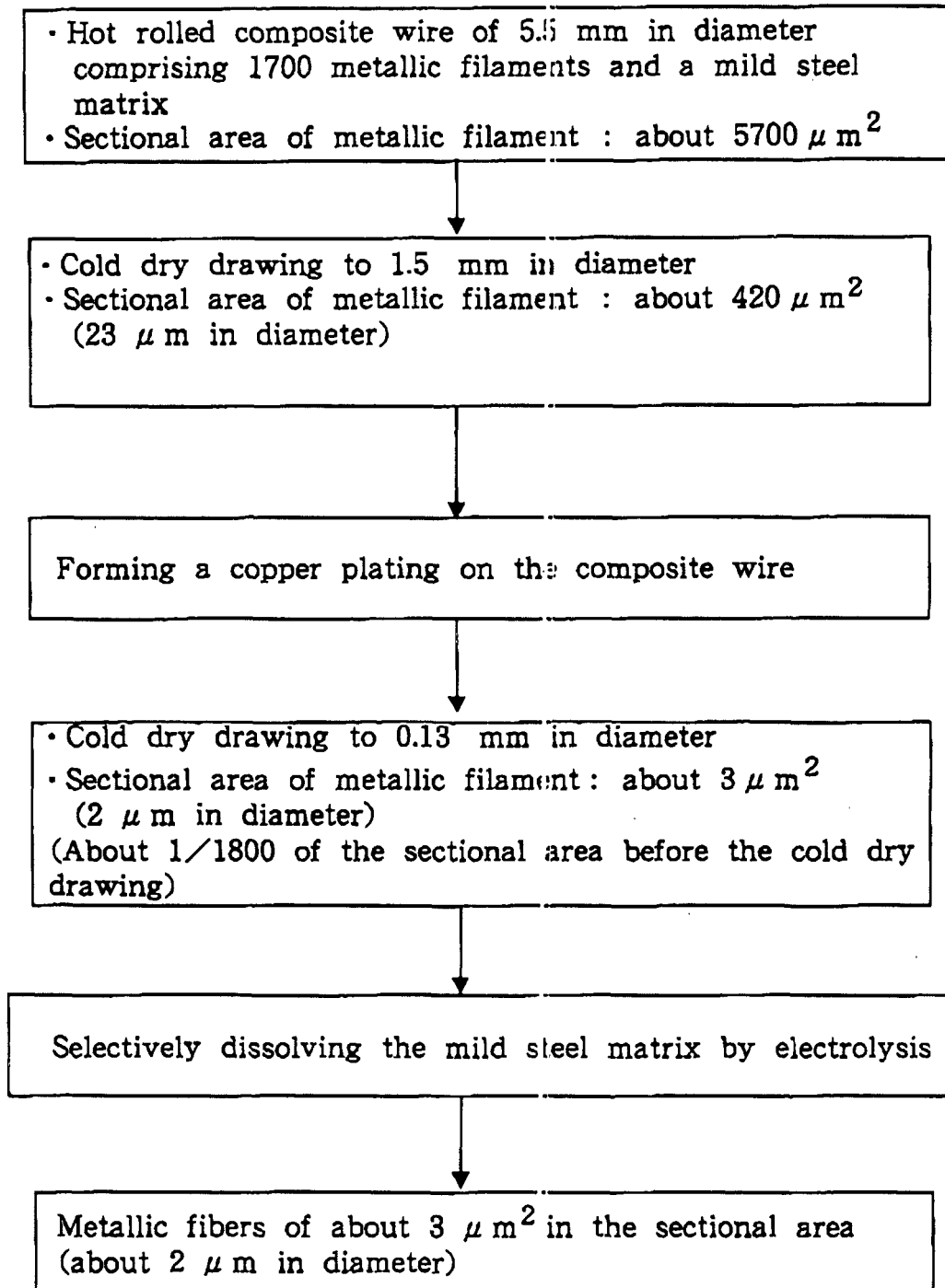


Fig.5

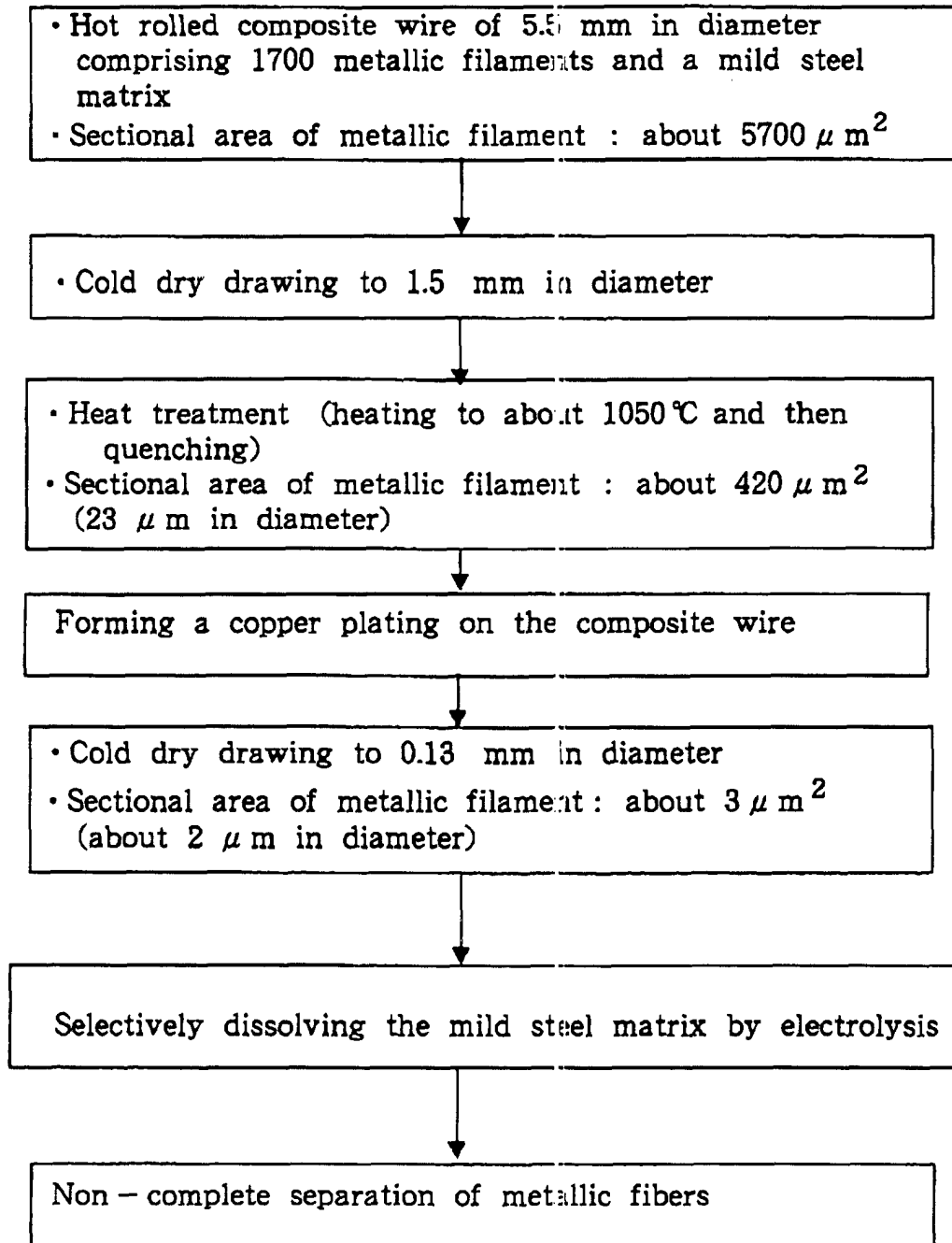


Fig.6

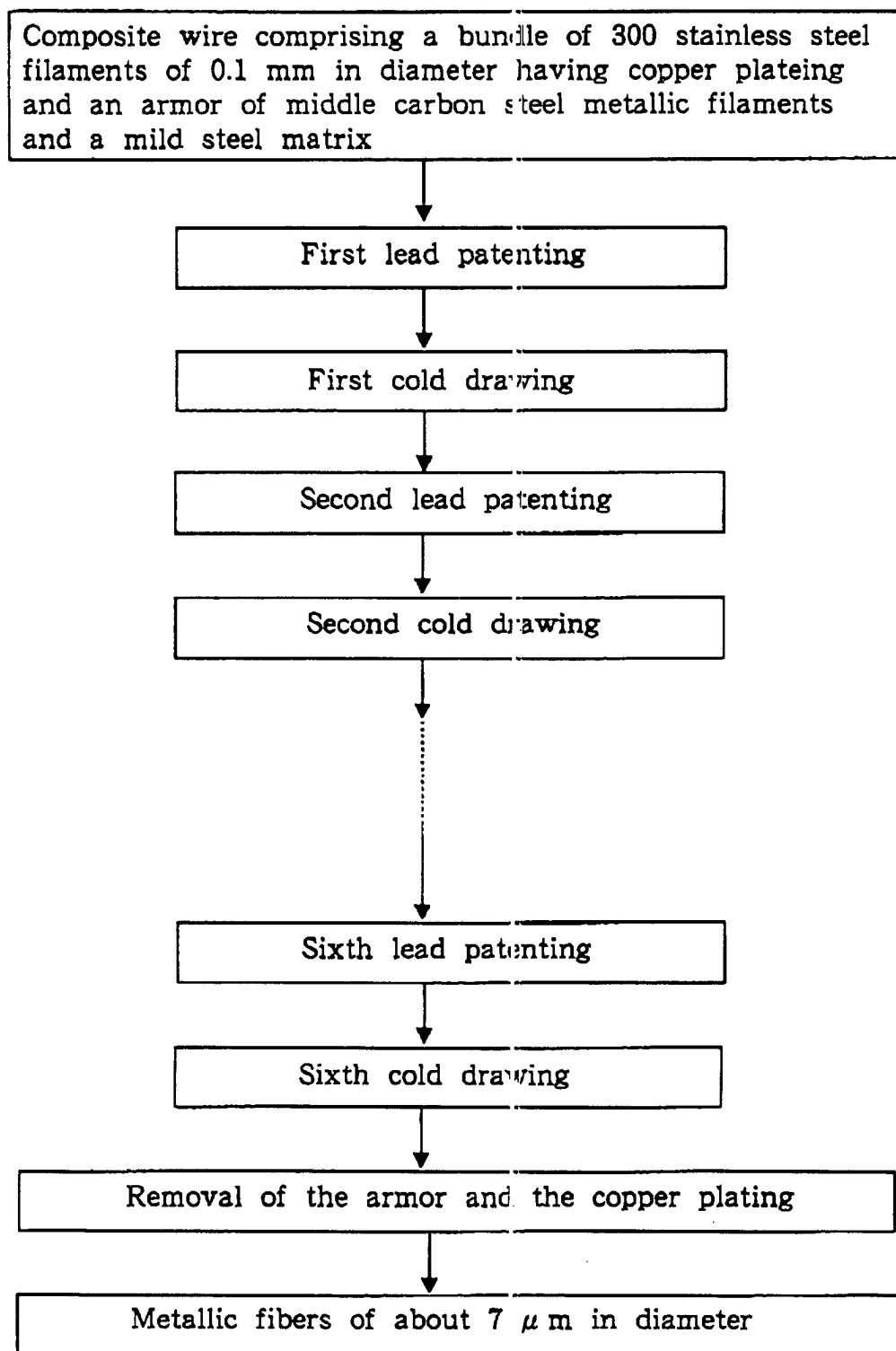
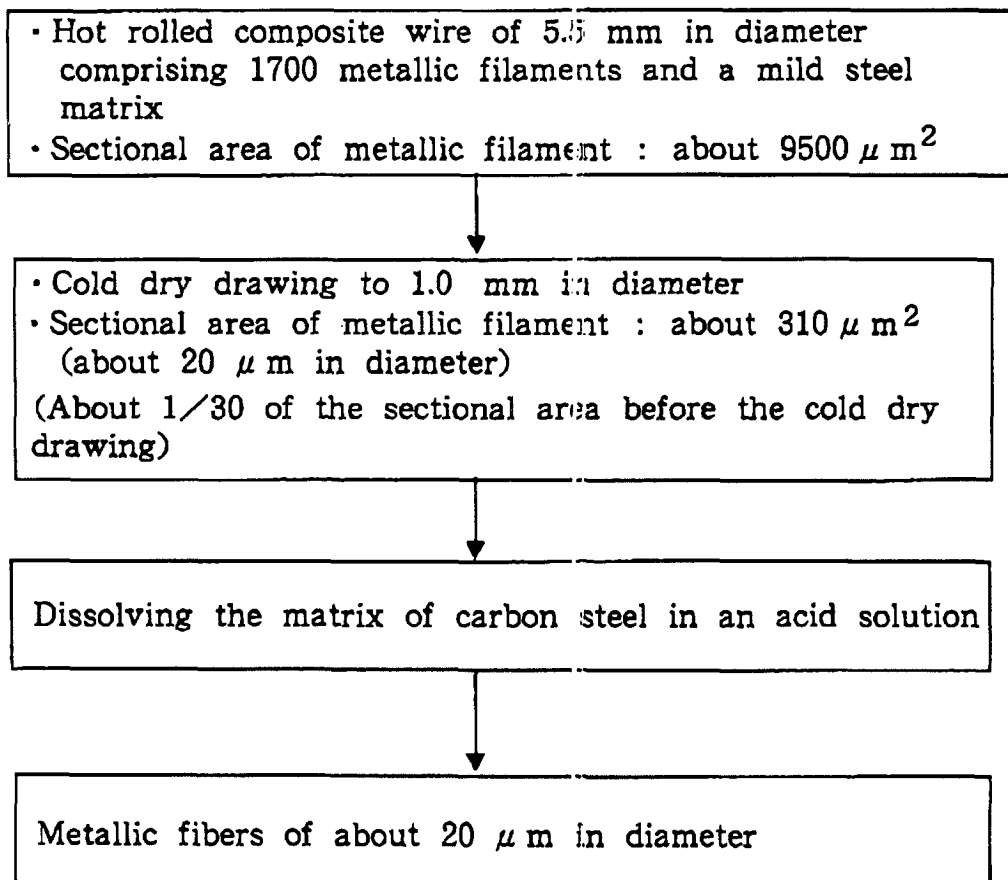


Fig.7





European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 00 30 1514

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			B21C
Place of search		Date of completion of the search	Examiner
THE HAGUE		31 July 2000	Barrow, J
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