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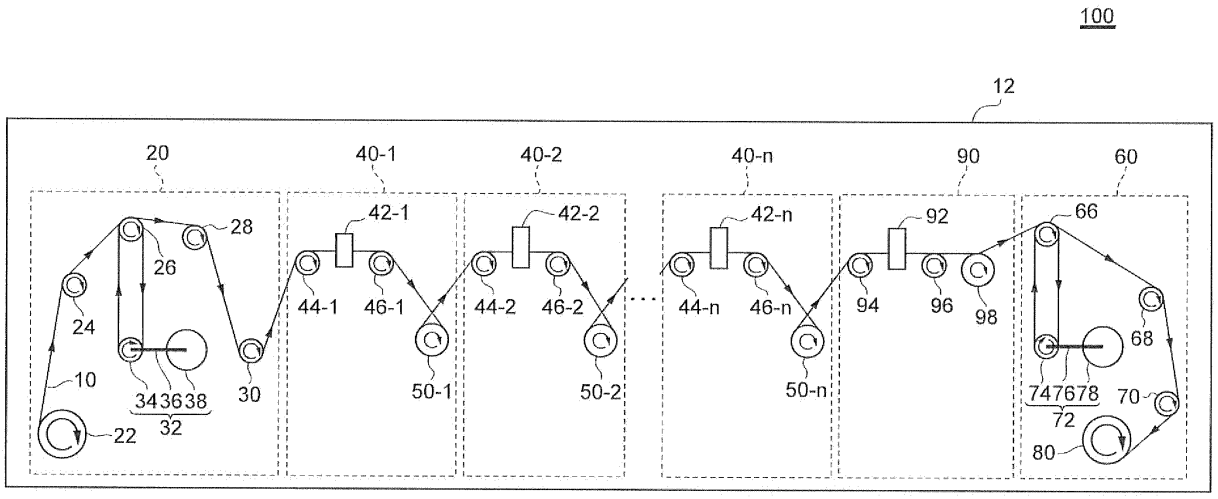
(54) WIRE DRAWING MACHINE AND WIRE DRAWING METHOD

(57) A non-siip wire drawing machine with a reduced number of dancers is provided. The wire drawing machine comprises: a first wire drawing die for reducing a diameter of a metal wire passing therethrough, thereby drawing the metal wire; a back tension control unit that controls a first back tension of the metal wire passing through the first wire drawing die; a first capstan that pulls the metal wire passing through the first wire drawing die at a first front tension through the first wire drawing die in a non-slip manner; a first front tension measuring unit that measures the first front tension; a first capstan control unit that controls a rotation torque of the first capstan based on the measured first front tension; and a winding unit that winds up the drawn metal wire.

FIG.1



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Description

Technical Field

[0001] The present invention relates to a wire drawing machine and wire drawing method for drawing metal wires. The invention particularly relates to a wire drawing machine and wire drawing method for drawing metal wires in a non-slip manner.

Background Art

[0002] One example of a conventional wire drawing machine is described in JP2003-053418 A (Patent Document 1), and it is called a slip-type wire drawing machine. Such conventional slip-type wire drawing machine sets the rotation speed of a capstan higher than the speed of the metal wire so as to cause a slip between the capstan and the metal wire and, using the capstan, the metal wire is pulled through a wire drawing die, thereby drawing the metal wire.

Prior Art References

Patent Documents

[0003] Patent Document 1: JP2003-053418 A

Summary of the Invention

Problem to be Solved by the Invention

[0004] Such conventional slip-type wire drawing machine needs to strictly control the rate of slip; however, controlling the slip rate is difficult, particularly when drawing fine-diameter metal wires, and this is a problem.

Means for Solving the Problem

[0005] In order to solve the above problem, according to a first aspect of the invention, a wire drawing machine is provided which comprises: a first wire drawing die for reducing a diameter of a metal wire passing therethrough, thereby drawing the metal wire; a back tension control unit that controls a first back tension of the metal wire passing through the first wire drawing die; a first capstan that pulls the metal wire passing through the first wire drawing die at a first front tension through the first wire drawing die in a non-slip manner; a first front tension measuring unit that measures the first front tension; a first capstan control unit that controls a rotation torque of the first capstan based on the measured first front tension; and a winding unit that winds up the drawn metal wire.

[0006] The above wire drawing machine may further comprise a second wire drawing die which is provided between the first capstan and the winding unit and through which the metal wire pulled out by the first capstan passes, so as to reduce the diameter of the metal wire passing therethrough, thereby drawing the metal wire. The first capstan may deliver the metal wire to the second wire drawing die in a non-slip manner, and the first capstan control unit may control the rotation torque of the first capstan based on the first front tension so that the metal wire passing through the second wire drawing die has a second back tension of a predetermined value.

[0007] The above wire drawing machine may further comprise: a second capstan that pulls the metal wire passing through the second wire drawing die at a second front tension through the second wire drawing die in a non-slip manner; a third wire drawing die which is provided between the second capstan and the winding unit and through which the metal wire pulled out by the second capstan passes, so as to reduce the diameter of the metal wire passing therethrough, thereby drawing the metal wire; a second front tension measuring unit that measures the second front tension; and a second capstan control unit that controls a rotation torque of the second capstan based on the measured second front tension, and the second capstan control unit may control the rotation torque of the second capstan based on the second front tension so that the metal wire passing through the third wire drawing die has a third back tension of a predetermined value.

[0008] The above wire drawing machine may further comprise an unwinding unit that delivers the metal wire to the first wire drawing die, and the back tension control unit may be a dancer that controls the first back tension of the metal wire between the unwinding unit and the first wire drawing die.

[0009] According to a second aspect of the invention, a wire drawing machine is provided which comprises: a first wire drawing die for reducing a diameter of a metal wire passing therethrough, thereby drawing the metal wire; a back tension control unit that controls a first back tension of the metal wire passing through the first wire drawing die; a first

capstan that pulls the metal wire passing through the first wire drawing die in a non-slip manner through the first wire drawing die; a first capstan control unit that controls a rotation torque of the first capstan so as to pull the metal wire through the first wire drawing die; and a winding unit that winds up the drawn metal wire, wherein the first capstan control unit stores, in advance, a first front tension of the metal wire obtained when pulling the metal wire through the first wire drawing die by rotating the first capstan at a controlled speed, and wherein the first capstan control unit controls the rotation torque of the first capstan based on the first front tension so as to pull the metal wire through the first wire drawing die.

[0010] In the above wire drawing machine, the first capstan control unit may store, as the first front tension, an average torque of the first capstan obtained when pulling the metal wire through the first wire drawing die by rotating the first capstan at a controlled speed for a predetermined period of time.

[0011] The above wire drawing machine may further comprise: a second wire drawing die which is provided between the first capstan and the winding unit and through which the metal wire pulled out by the first capstan passes, so as to reduce the diameter of the metal wire passing therethrough, thereby drawing the metal wire; and a back tension measuring unit that measures a second back tension of the metal wire passing through the second wire drawing die. The first capstan may deliver the metal wire to the second wire drawing die in a non-slip manner, and the first capstan control unit may control the rotation torque of the first capstan so that the measured second back tension becomes a predetermined value.

[0012] According to a third aspect of the invention, a wire drawing method for drawing a metal wire by causing the metal wire to pass through a wire drawing die so as to reduce a diameter of the metal wire is provided, the method comprising the steps of: controlling a back tension of the metal wire passing through the wire drawing die; pulling the metal wire passing through the wire drawing die at a predetermined front tension through the wire drawing die in a non-slip manner using a capstan; measuring the front tension; and controlling a rotation torque of the capstan based on the measured front tension.

[0013] According to a fourth aspect of the invention, a wire drawing method for drawing a metal wire by causing the metal wire to pass through a wire drawing die so as to reduce a diameter of the metal wire is provided, the method comprising: a step of controlling a back tension of the metal wire passing through the wire drawing die; a step of pulling the metal wire passing through the wire drawing die in a non-slip manner through the wire drawing die using a capstan; and a controlling step of controlling a rotation torque of the capstan, and the controlling step comprises the steps of: storing, in advance, a front tension of the metal wire obtained when pulling the metal wire through the wire drawing die by rotating the capstan at a controlled speed; and controlling the rotation torque of the capstan based on the front tension so as to pull the metal wire through the wire drawing die.

Brief Description of the Drawings

[0014]

Fig. 1 is a schematic view showing a configuration of a wire drawing machine 100 according to an embodiment of the invention.

Fig. 2 is a block diagram illustrating a configuration of a control unit 200 that controls the wire drawing machine 100.

Mode for Carrying out the Invention

[0015] Hereinafter, with reference to the attached drawings, the invention will be described through embodiments thereof. However, the below-described embodiments do not limit the invention defined in the claims and all combinations of features described in the embodiments are not necessarily indispensable for the solution according to the invention.

Configuration of Wire Drawing Machine 100

[0016] Fig. 1 is a schematic view showing a configuration of a wire drawing machine 100 according to an embodiment of the invention. Fig. 2 is a block diagram illustrating a configuration of a control unit 200 that controls the wire drawing machine 100 in the above embodiment.

[0017] In the present embodiment, the wire drawing machine 100 is configured so as to include a housing 12, an unwinding unit 20, wire drawing units 40 and 90, a winding unit 60 and a control unit 200 that controls each unit. In the wire drawing machine 100, the unwinding unit 20, the wire drawing units 40 and 90 and the winding unit 60 are arranged in this order along the route through which a metal wire 10 is delivered out, drawn and wound (hereinafter referred to as the "passage"), from upstream to downstream (from left to right in Fig. 1). The wire drawing machine 100 draws the metal wire delivered from the unwinding unit 20 sequentially at the respective wire drawing units 40 and 90 by reducing

the diameter thereof, and winds up the drawn metal wire 10 at the winding unit 60.

[0018] The control unit 200 controls the operation of the wire drawing machine 100. The control unit 200 is configured so as to have a system controller 110, an unwinding unit controller 120, a wire drawing unit controller 140 and a winding unit controller 160. The system controller 110 is connected to the unwinding unit controller 120, the wire drawing unit controller 140 and the winding unit controller 160, and performs overall control of each unit controller.

[0019] The unwinding unit controller 120, the wire drawing unit controller 140 and the winding unit controller 160 are connected to various components provided in the unwinding unit 20, the wire drawing units 40 and 90 and the winding unit 60, respectively, and control the respective units. Although only one wire drawing unit controller 140 is shown in Fig. 2, a wire drawing unit controller 140 is provided for each of the n stages of wire drawing units 40-1 to 40-n (n being a positive integer) and the wire drawing unit 90.

[0020] The system controller 110, and the unwinding unit controller 120, the wire drawing unit controller 140 and the winding unit controller 160 provided in the control unit 200 control the unwinding unit 20, the wire drawing unit 40 and the winding unit 60 as stated above, so as to deliver the metal wire 10 from the unwinding unit 20, draw it by causing it to pass through the respective wire drawing units 40-1 to 40-n and 90, and wind it up at the winding unit 60.

[0021] Each structure in the wire drawing machine 100 will be described below, referring to Figs. 1 and 2. In the present embodiment, as illustrated in Fig. 1, n stages of wire drawing units 40 and the wire drawing unit 90 are serially arranged between the unwinding unit 20 and the winding unit 60 along the route through which the metal wire 10 is delivered, so as to sequentially draw the metal wire 10. In the below description, the wire drawing units 40 are respectively referred to as wire drawing units 40-1 to 40-n along the direction extending from the unwinding unit 20 toward the winding unit 60.

Unwinding Unit 20

[0022] The unwinding unit 20 is configured so as to have an unwinding bobbin 22, guide rollers 24, 26, 28 and 30, and a dancer section 32. In the unwinding unit 20, the metal wire 10 is provided so as to run across the unwinding bobbin 22, the guide roller 24, the guide roller 26, a dancer roller 34, the guide roller 26 and the guide roller 28, in this order, with a predetermined tension being applied thereto (hereinafter, the metal wire provided as such will be described as being "provided in a tensioned state").

[0023] The unwinding bobbin 22 is rotatably mounted in the housing 12 of the wire drawing machine 100. The unwinding bobbin 22 is connected to an unwinding motor 122 and rotates when driven by the motor. With that rotation, the metal wire 10 wound around the unwinding bobbin 22 is pulled out and delivered to the passage. In the present embodiment, the unwinding bobbin 22 is driven by the unwinding motor 122 at a controlled speed. That is, the unwinding unit controller 120 controls the drive of the unwinding motor 122 so that the unwinding bobbin 22 rotates at a predetermined speed.

[0024] The guide rollers 24, 26, 28 and 30 are rotatably mounted in the housing 12 of the wire drawing machine 100. The metal wire 10 is wound around each of the guide rollers 24, 26, 28 and 30 a predetermined number of times so as to allow the metal wire 10 to be delivered in a non-slip manner. The guide rollers 24, 26, 28 and 30 rotate due to tension applied to the metal wire 10 by the wire drawing unit 40, so that the metal wire 10 delivered from the unwinding bobbin 22 is sequentially delivered in a non-slip manner along the passage.

[0025] The dancer section 32 is configured so as to include the dancer roller 34, a dancer arm 36 and a torque motor 38, and applies a desired tension to the metal wire 10 delivered from the unwinding bobbin 22.

[0026] The dancer roller 34 is rotatably supported at one end of the dancer arm 36 having a rod shape. The metal wire 10 is provided in a tensioned state across the guide roller 24, the guide roller 26, the dancer roller 34, the guide roller 26 and the guide roller 28 in this order and a predetermined tension is applied to the metal wire 10 by the dancer roller 34 in a downward direction in Fig. 1.

[0027] The dancer arm 36 is arranged approximately horizontally in Fig. 1, i.e. in a direction approximately perpendicular to the direction in which tension is applied to the metal wire 10 by the dancer roller 34. This horizontal arrangement is regarded as a reference position for the dancer arm 36. The other end of the dancer arm 36 is supported so as to be fixed to a drive shaft of the torque motor 38 and the drive shaft of the torque motor 38 acts as the pivot point of the dancer arm 36.

[0028] A potentiometer 138 (Fig. 2) is provided at the drive shaft of the torque motor 38 and it detects a pivot angle of the dancer arm 36. The potentiometer 138 is connected to the unwinding unit controller 120 and provides the pivot angle detected by the potentiometer 138 to the wire drawing unit controller 120. It should be noted that, although the potentiometer 138 detects a pivot angle of the dancer arm 36 in the present embodiment, the potentiometer 138 may detect a position or displacement of the dancer roller 34, for example, a position or displacement of the dancer roller 34 in a direction in which tension is applied to the metal wire 10 by the dancer roller 34. In that case, tension may be applied to the metal wire 10 by vertically moving the dancer roller 34 (linearly moving it in a direction of applying tension to the metal wire), instead of rotating the dancer roller 34.

[0029] The torque motor 38 applies a predetermined tension to the metal wire 10 through the dancer arm 36 and the dancer roller 34. That is, the torque motor 38 transmits its rotation torque to the metal wire 10 through the dancer arm

36 and the dancer roller 34, thereby applying tension to the metal wire 10. The torque motor 38 is connected to the unwinding unit controller 120 and generates a predetermined rotation torque based on the commands (torque commands) from the unwinding unit controller 120.

[0030] By transmitting the predetermined torque generated by the torque motor 38 to the metal wire 10 through the dancer arm 36 and the dancer roller 34 with the above configuration, the dancer section 32 applies a particular set tension to the metal wire 10. In other words, the tension applied to the metal wire 10 delivered from the unwinding unit 20 is determined according to the rotation torque of the torque motor 38.

[0031] As described above, in the unwinding unit 20 of the present embodiment, the dancer section 32 applies a predetermined tension to the metal wire 10 delivered from the unwinding bobbin 22 at a constant speed and this allows the metal wire 10 to be delivered to the wire drawing unit 40-1 with a desired tension being applied.

Wire Drawing Unit 40

[0032] In the present embodiment, the wire drawing machine 100 is configured so as to have n stages of wire drawing units 40-1 to 40-n and wire drawing unit 90 as the last stage between the unwinding unit 20 and the winding unit 60. The unwinding unit 20, the wire drawing units 40-1 to 40-n and 90, and the winding unit 60 are provided so as to be connected therebetween. The metal wire 20 delivered from the unwinding unit 20 sequentially passes through the wire drawing units 40-1, 40-2, ... 40-n and 90 in this order and is thereby drawn. The drawn metal wire 10 in the wire drawing unit 90 is then delivered to the winding unit 60. Since the wire drawing units 40-1 to 40-n have the same configuration in the present embodiment, the wire drawing units 40-1 to 40-n will hereinafter be collectively referred to as a "wire drawing unit 40" unless the wire drawing units 40-1 to 40-n are individually specified. Further, each of the structures included in the wire drawing units 40-1 to 40-n will also be referred to collectively.

[0033] The wire drawing unit 40 is configured so as to have a wire drawing die 42, guide rollers 44 and 46, and a drive capstan 50. In the wire drawing unit 40, the metal wire 10 is provided in a tensioned state across the guide roller 44, the wire drawing die 42, the guide roller 46 and the drive capstan 50.

[0034] The wire drawing die 42 is disposed between the guide roller 44 and the guide roller 46. The wire drawing die 42 has a die hole extending along the direction in which the metal wire 10 is provided in a tensioned state. When the metal wire 10 passes and is pulled through the die hole, the diameter of the metal wire 10 is reduced and the metal wire 10 is accordingly drawn. Here, the reduction rate of the diameter (the reduction rate of the cross section) of the metal wire 10 is determined according to the diameter of the die hole provided in the wire drawing die 42, and the metal wire 10 is drawn according to the reduction rate. In each stage of the wire drawing units 40-1 to 40-n, the die hole diameter of the wire drawing die 42 is selected as appropriate so that the metal wire 10 drawn at the wire drawing unit 40-n, as the last stage, will have a desired wire diameter.

[0035] In the present embodiment, the wire drawing units 40-1 to 40-n gradually reduce the diameter of the metal wire 10 that passes therethrough. Accordingly, the die hole formed in the wire drawing die 42-n has a smaller diameter than that of the die hole formed in the wire drawing die 42-1. Further, the die hole formed in the wire drawing die 42-2 has a smaller diameter than that of the die hole formed in the wire drawing die 42-1.

[0036] In the present embodiment, the wire drawing die 42 is stored in a die holder fixed to the housing 12. The wire drawing machine 100 may have means for measuring, when the metal wire 10 is pulled and drawn through the wire drawing die 42, a force of such drawing. Such means may be, for example, means for detecting a force with which the wire drawing die 42 presses the die holder, which thereby measures the drawing force, and may alternatively be means for detecting a distortion of the die holder fixed to the housing 12, which thereby measures the drawing force.

[0037] Here, if the metal wire 10 and/or the wire drawing die 42 are immersed with lubricating oil, vibration, etc., of the metal wire 10 passing through the wire drawing die 42 can be prevented, resulting in improved stability. Accordingly, an oil tank for immersing the metal wire 10 and/or the wire drawing die 42 with lubricating oil may be provided. For example, an oil tank may be arranged between the wire drawing die 42 and the guide roller 44 and the metal wire 10 may be configured so as to pass through the oil tank. In that case, it is preferable to provide means for supplying lubricating oil to the oil tank such that the lubricating oil flows over the oil tank during the wire drawing operation. Alternatively, an oil tank may be arranged so as to contain the wire drawing die 42 therein and the metal wire 10 may be configured so as to pass through the oil tank vertically or horizontally. It should be noted, however, that a seal is needed at the portion through which the wire extends.

[0038] Immersing the metal wire 10 and/or the wire drawing die 42 with lubricating oil provides the following advantages. An optimum lubricating oil can be used for the wire drawing performed at the wire drawing die 42 in each wire drawing unit 40, The composition of the lubricating oil greatly affects the wearing of the wire drawing die 42, and the above configuration enables a lubricating oil having a composition specialized for wire drawing to be stably supplied. Furthermore, a circulation and cleaning system for the lubricating oil, which would be necessary to reduce the effects of contamination in the oil caused by abrasion between the metal wire 10 and the drive capstan 50, can be simplified and this leads to reduced manufacturing costs.

[0039] The guide rollers 44 and 46 are rotatably mounted in the housing 12 of the wire drawing machine 100. The guide rollers 44 and 46 respectively have distortion gauges 152 and 156 and encoders 154 and 158 (see Fig. 2) at their respective shafts.

[0040] The distortion gauges 152 and 156 detect distortion of the guide rollers 44 and 46, respectively, so as to detect the tension of the metal wire 10. The metal wire 10 provided in the wire drawing machine 100 in a tensioned state has a certain tension at each location, and the distortion gauge 152 detects distortion of the guide roller 44, thereby detecting a tension of the metal wire 10 before passing through the wire drawing die 42 (hereinafter referred to as a "front tension"). Meanwhile, the distortion gauge 156 detects distortion of the guide roller 46, thereby detecting a tension of the metal wire 10 after passing through the wire drawing die 42 (hereinafter referred to as a "back tension"). More specifically, the distortion gauge 152 (156) obtains a tension of the metal wire 10 in its delivery direction when the metal wire 10 enters the guide roller 44 (46) and also obtains a tension of the metal wire 10 in its delivery direction when the metal wire 10 exits the guide roller 44 (46), and detects the resultant force of the obtained tensions as such distortion.

[0041] The encoders 154 and 158 detect the speed of rotation of the guide rollers 44 and 46, respectively, thereby detecting the speed at which the metal wire 10 is delivered. Specifically, the encoder 154 detects the speed of rotation of the guide roller 44, thereby detecting the speed at which the metal wire 10 is delivered in front of the wire drawing die 42. Meanwhile, the encoder 158 detects the speed of rotation of the guide roller 46, thereby detecting the speed at which the metal wire 10 is delivered behind the wire drawing die 42.

[0042] The drive capstan 50 is rotatably mounted in the housing 12 of the wire drawing machine 100. A drive motor 150 (see Fig. 2) is connected to the drive capstan 50 and the drive capstan 50 rotates at a predetermined torque based on the commands from the wire drawing unit controller 140. With the rotation torque, the drive capstan 50 pulls the metal wire 10 through the wire drawing die 42 and delivers the pulled metal wire 10 to the next stage wire drawing unit 40 or to the wire drawing unit 90.

[0043] The outer surface of the drive capstan 50 is thermal-sprayed so as to increase the hardness of the surface and enhance durability and also to prevent a slip from occurring between the surface (surface in contact with the metal wire 10) of the drive capstan 50 and the metal wire 10. The outer surface of the drive capstan 50 may alternatively be coated with an elastic body having a large coefficient of friction (e.g., resins such as urethane and rubber). Such surface-treated drive capstan 50 allows the metal wire 10 to be pulled through the wire drawing die 42 in a non-slip manner and to be delivered to the next stage.

Wire Drawing Unit 90

[0044] The wire drawing unit 90 is configured so as to have a wire drawing die 92, guide rollers 94 and 96, and a drive capstan 98. In the wire drawing unit 90, the metal wire 10 is provided in a tensioned state across the guide roller 94, the wire drawing die 92, the guide roller 96 and the drive capstan 98.

[0045] Here, the guide rollers 94 and 96 have configurations approximately the same as or similar to those of the guide rollers 44 and 46 in the wire drawing unit 40. Further, the drive capstan 98 has a configuration approximately the same as or similar to that of the drive capstan 50 in the wire drawing unit 40, except that the speed thereof is controlled by the wire drawing unit controller 140.

[0046] The wire drawing die 92 has a configuration approximately the same as or similar to the configuration of the wire drawing die 42 in the wire drawing unit 40, except that it has a function of properly adjusting (adding or reducing) the stress and distortion in the metal wire 10. More specifically, the wire drawing die 92 is configured so as to be able to freely adjust the angle of the central axis of the die hole relative to the direction in which the metal wire 10 is pulled therethrough. The wire drawing die 92 is also configured so as to be able to freely adjust the position of the die hole in a direction approximately perpendicular to the direction in which the metal wire 10 is pulled therethrough. With this configuration, the metal wire 10 can be made in a straight line or curled as required. Further, since the axial direction of the die hole can be adjusted according to the direction of drawing the metal wire 10, uneven wearing of the die can be suppressed.

Winding Unit 60

[0047] The winding unit 60 is configured so as to have guide rollers 66, 68 and 70, a dancer section 72 and a winding bobbin 80. In the winding unit 60, the metal wire 10 is provided in a tensioned state across the guide roller 66, a dancer roller 74, the guide roller 66, the guide roller 68, the guide roller 70 and the winding bobbin 80, in this order.

[0048] The guide rollers 66, 68 and 70 are rotatably mounted in the housing 12 of the wire drawing machine 100. The metal wire 10 is wound around each of the guide rollers 66, 68 and 70 a predetermined number of times so as to allow the metal wire 10 to be delivered in a non-slip manner. The guide rollers 66, 68 and 70 rotate due to tension applied to the metal wire 10 by the rotation of the winding bobbin 80, so that the drawn metal wire 10 in the wire drawing unit 90 is sequentially delivered in a non-slip manner along the passage.

[0049] The dancer section 72 is configured so as to include the dancer roller 74, a dancer arm 76 and a torque motor 78, and applies a desired tension to the drawn metal wire 10 in the wire drawing unit 90.

[0050] The dancer roller 74 is rotatably supported at one end of the rod-shaped dancer arm 76. The metal wire 10 is provided in a tensioned state across the guide roller 66, the dancer roller 74, the guide roller 66, the guide roller 68 and the guide roller 70 in this order and a predetermined tension is applied to the metal wire 10 by the dancer roller 74 in a downward direction in Fig. 1.

[0051] The dancer arm 76 is arranged approximately horizontally in Fig. 1, i.e., in a direction approximately perpendicular to the direction in which tension is applied to the metal wire 10 by the dancer roller 74. This horizontal arrangement is regarded as a reference position for the dancer arm 76. The other end of the dancer arm 76 is supported so as to be fixed to a drive shaft of the torque motor 78 and the drive shaft of the torque motor 78 acts as the pivot point of the dancer arm 76.

[0052] A potentiometer 178 (Fig. 2) is provided at the drive shaft of the torque motor 78 and it detects a pivot angle of the dancer arm 76. The potentiometer 178 is connected to the winding unit controller 160 and provides the pivot angle detected by the potentiometer 178 to the winding unit controller 160.

[0053] The torque motor 78 applies a predetermined tension to the metal wire 10 through the dancer arm 76 and the dancer roller 74. That is, the torque motor 78 transmits its rotation torque to the metal wire 10 through the dancer arm 76 and the dancer roller 74, thereby applying tension to the metal wire 10. The torque motor 78 is connected to the winding unit controller 160 and generates a predetermined rotation torque based on the commands (torque commands) from the winding unit controller 160.

[0054] The winding bobbin 80 is rotatably mounted in the housing 12 of the wire drawing machine 100. The winding bobbin 80 is connected to a winding motor 180 and rotates when driven by the motor. With that rotation, the drawn metal wire 10 in the wire drawing unit 90 is wound around the winding bobbin 80. In the present embodiment, the winding bobbin 80 is driven by the winding motor 180 at a controlled speed. That is, the winding unit controller 160 controls the drive of the winding motor 180 so that the winding bobbin 80 rotates at a predetermined speed. More specifically, the winding unit controller 160 controls the rotation speed of the winding motor 180 based on the rotation speed of the drive capstan 98 and the pivot angle of the dancer arm 76.

[0055] As described above, in the winding unit 60 according to the present embodiment, while the dancer section 72 applies a predetermined tension to the metal wire 10 delivered from the wire drawing unit 90, the winding bobbin 80 winds up the metal wire 10 at a constant speed.

Wire Drawing Operation of Wire Drawing Apparatus 100

[0056] Next, the operation of the wire drawing machine 100 having the above-described configuration so as to draw the metal wire 10 will be described with reference to Figs. 1 and 2. In the below examples, BTi and FTi respectively represent the back tension and front tension of the metal wire 10 to be drawn by the wire drawing die 42 of the i-th stage wire drawing unit 40 from among the n stages of the wire drawing units 40, and CTi represents the rotation torque of the drive capstan 50 of the i-th stage wire drawing unit 40 (with i being a positive integer equal to or smaller than n).

First Example

[0057] In the first example, the metal wire 10 is drawn by controlling the rotation torque of the drive capstan 50 based on the front tension of the metal wire 10 in each wire drawing unit 40. More specifically, after providing the metal wire 10 in a tensioned state across each structure in the unwinding unit 20, the wire drawing units 40 and the winding unit 60, the metal wire 10 is drawn by controlling each structure as set out below.

Operation of Unwinding Unit 20

[0058] First, the unwinding unit 20 causes the metal wire 10 to be delivered out from the unwinding unit 20 at an approximately constant speed. Specifically, the unwinding unit controller 120 controls the speed of rotation of the unwinding motor 122 so that the speed at which the metal wire 10 is delivered out from the unwinding unit 20 (hereinafter a speed at which the metal wire 10 is delivered at a particular point of the passage will be referred to as a "wire speed") is maintained at an approximately constant value according to the speed at which the metal wire 10 is to be delivered out from the drive capstan 98.

[0059] In the present embodiment, the unwinding unit controller 120 controls the speed of rotation of the unwinding motor 122 by using the wire speed of the metal wire 10 at the guide roller 44 as a feed-forward signal and the pivot angle of the dancer arm 36 as a feedback signal. More specifically, the speed at which the metal wire 10 is delivered out from the unwinding unit 20, namely, the wire speed of the metal wire 10 passing through the guide roller 44, is detected by the encoder 154 provided at the guide roller 44 and fed to the wire drawing unit controller 140. Then, the unwinding unit

controller 120 provides a speed signal indicative of the detected wire speed to the unwinding motor 122 as a feed-forward signal, thereby controlling the rotation of the unwinding motor 122.

[0060] Meanwhile, when the dancer arm 36 pivots and a predetermined tension is accordingly applied to the metal wire 10 delivered from the unwinding bobbin 22, a certain difference is created between the wire speed of the metal wire 10 delivered from the unwinding bobbin 22 and the wire speed of the metal wire 10 passing through the guide roller 44. The unwinding unit controller 120 generates a feedback signal based on such pivot angle detected by the potentiometer 138 and controls the rotation of the unwinding motor 122 so as to correct a deviation in wire speed due to the above difference, thereby maintaining the wire speed of the metal wire 10 delivered out from the unwinding unit 20 at an approximately constant value.

[0061] To be more specific, the unwinding unit controller 120 calculates a pivot angle deviation between such pivot angle of the dancer arm 36 detected by the potentiometer 138 and the pivot angle of the dancer arm 36 at the reference position. Then, the unwinding unit controller 120 determines the rotation speed of the unwinding motor 122 so as to approximate the calculated pivot angle deviation to zero, and provides a rotation speed command to the unwinding motor 122 based on such determination. Using the pivot angle deviation as a feedback signal, the unwinding unit controller 120 controls the rotation speed of the unwinding motor 122 through P control, PI control, PID control, etc.

[0062] In order to deliver the metal wire 10 wound around the unwinding bobbin 22 at a constant speed, it is necessary to control the speed of rotation of the unwinding bobbin 22 according to the winding diameter of the metal wire 10 wound around the unwinding bobbin 22, and, in this respect, with the above-stated operation, the unwinding unit 20 maintains the wire speed of the metal wire 10 delivered from the unwinding unit 20 at an approximately constant value and, at the same time, the unwinding unit 22 applies a predetermined tension so that the metal wire 10 has a tension set in advance. The tension acts as a back tension BT1 of the metal wire 10 passing through the wire drawing die 42-1. For example, the unwinding unit controller 120 controls the unwinding unit 20 and applies a predetermined tension to the metal wire 10 so that BT1 is about 10% of the yield stress of the metal wire 10 wound around the unwinding bobbin 22.

[0063] Although the unwinding unit controller 120 in the present embodiment controls the speed of rotation of the unwinding motor 122 so as to maintain the wire speed of the metal wire 10 at an approximately constant value while controlling the pivot angle of the dancer arm 36 so as to apply a predetermined tension to the metal wire 10, the tension and/or the wire speed of the metal wire 10 may be controlled by not providing a dancer section 32 and configuring the unwinding unit controller 120 to control the speed of rotation and/or the rotation torque of the unwinding motor 122. With this configuration, the number of dancer sections 32 in the wire drawing machine 100 can be further reduced.

[0064] Further, in the unwinding unit 20, for example, a distortion gauge, etc., may be provided in the guide roller 28 or 30 so as to measure the tension of the metal wire 10. In that case, the unwinding unit controller 120 may feedback-control the rotation torque of the torque motor 38 by using the difference between a set tension and the tension measured by such distortion gauge, etc., as a feedback signal. This allows a predetermined tension to be applied to the metal wire 10 so that the resulting tension of the metal wire 10 is further closer to the set tension.

Operation of Wire Drawing Units 40

[0065] Next, the operation of each wire drawing unit 40 drawing the metal wire 10 delivered from the unwinding unit 20 will be described.

[0066] The first-stage wire drawing unit 40-1 draws the metal wire 10 by controlling the rotation torque CT1 of the drive capstan 50-1 based on the front tension FT1 of the metal wire 10 passing through the wire drawing die 42-1. More specifically, the rotation torque CT1 of the drive capstan 50-1 has the following relationship with the front tension FT1 of the metal wire 10 passing through the wire drawing die 42-1 and the back tension BT2 of the metal wire 10 passing through the wire drawing die 42-2 of the second-stage wire drawing unit 40-2:

$$CT1=FT1-BT2$$

[0067] Accordingly, if the front tension FT1 of the first stage can be measured, the back tension BT2 of the second stage can be controlled to a predetermined value by controlling the rotation torque CT1 of the first stage. In this example, the wire drawing unit controller 140 controls the rotation torque CT1 of the drive capstan 50-1 based on the front tension FT1 of the metal wire 10 measured by the distortion gauge 156 provided at the guide roller 46-1, so that the back tension BT2 of the second stage becomes a predetermined value. In other words, the wire drawing unit controller 140 feed-forward-controls the rotation torque CT1 based on the front tension FT1. With this control, the metal wire 10 is pulled through the wire drawing die 42-1 by the drive capstan 50-1 with a pulling force of the front tension FT1 in a non-slip manner, and is delivered to the wire drawing unit 40-2 in a non-slip manner with the back tension BT2 being applied. The back tension BT2 is, for example, around 10% of the yield stress of the metal wire pulled through the wire drawing

die 42-1.

[0068] The second-stage wire drawing unit 40-2 further draws the metal wire 10 in the same manner as the first-stage wire drawing unit 40-1. That is, the wire drawing unit controller 140 controls the rotation torque CT2 of the drive capstan 50-2 based on the front tension FT2 of the metal wire 10 measured by the distortion gauge 156 provided at the guide roller 46-2, so that the back tension BT3 of the third stage becomes a predetermined value.

$$CT2=FT2-BT3$$

[0069] Similarly, the wire drawing unit controller 140 controls, in the i-th stage wire drawing unit 40-i, the rotation torque CTi of the drive capstan 50i based on the front tension FTi of the metal wire 10 measured by the distortion gauge 156 provided at the guide roller 46-i, so that the back tension BTi+1 of the i+1th stage becomes a predetermined value.

$$CT(i)=FT(i)-BT(i+1)$$

[0070] With the above control, the metal wire 10 is pulled through the wire drawing die 42i by the drive capstan 50i with a drawing force of the front tension FTi in a non-slip manner, and is delivered to the wire drawing unit 40i+1 (or wire drawing unit 90) in a non-slip manner with the back tension BTi+1 being applied. Note that, in the above formula, if i=n, then BT(i+1) is regarded as representing the back tension of the metal wire 10 to be drawn by the wire drawing die 92 in the wire drawing unit 90.

[0071] The wire drawing unit controller 140 in the present example controls the rotation torque CT of the drive capstan 50 based on the back tension BTi+1 which is a set value; however, the wire drawing unit controller 140 may control the rotation torque CT of the drive capstan 50 by measuring both the front tension FTi and the back tension BTi+1. Further, the rotation torque CT of the drive capstan 50 may be controlled by measuring the drawing force DT in each wire drawing die 42. By doing so, the drawing force in the wire drawing die 42 can be measured at the time of the wire drawing operation.

[0072] According to the present example, the drive capstan 50 sets the back tension BTi+1 of the next stage based on the actually measured front tension FTi. In other words, in the present example, since the front tension is actually measured in each stage, an error caused in the back tension of a particular stage (difference between the back tension set value and actual value) is not transferred to the front tension of the particular stage (or the back tension and front tension of the subsequent stages) and the error is, thus, not accumulated. In addition, the cause of errors between the back tension set value and actual value would be limited to mechanical errors in the drive capstan 50. Thus, according to the present example, a wire drawing machine with a sufficiently small difference between the back tension set value and actual value can be provided.

Operation of Wire Drawing Unit 90

[0073] Next, the operation of the wire drawing unit 90 drawing the metal wire 10 delivered from the wire drawing unit 40-n will be described. In the below description, the operation of the wire drawing unit 90 will be described mainly with regard to the differences from the operation of the wire drawing unit 40.

[0074] The wire drawing unit 90 properly adjusts the stress and distortion in the metal wire 10 drawn in the wire drawing unit 40-n and determines the wire speed of the metal wire 10 to be delivered to the winding unit 60.

[0075] More specifically, the metal wire 10 drawn by the wire drawing die 42-n of the wire drawing unit 40-n has stress or distortion in a direction perpendicular to the direction in which the metal wire 10 is delivered, particularly in the case where the wire drawing die has a large reduction in area. In the wire drawing die 92, however, a drawing force is applied to the metal wire 10 from its periphery more uniformly than in the wire drawing die 42-n, so that such stress or distortion can properly be adjusted.

[0076] Further, the drive capstan 98 determines the wire speed of the metal wire 10 in the wire drawing machine 100. Specifically, the wire drawing unit controller 140 supplies a rotation speed command to a drive motor 198 and controls the rotation of the drive motor 198, so that the wire speed of the metal wire 10 becomes a speed set in advance. The drive motor 198 controls the speed of rotation of the drive capstan 98 based on the above command. For example, the wire drawing unit controller 140 controls the speed of rotation of the drive capstan 98 so that the metal wire 10 delivered to the winding unit 60 has a wire speed of 1000 m/min.

[0077] The wire drawing unit controller 140 may measure the wire speed of the metal wire 10 delivered from the drive capstan 98 based on the speed of rotation of the guide roller 96 detected by the encoder 158 provided at the guide roller

96 and feedback-control the speed of rotation of the drive motor 198 using the measured wire speed as a feedback signal.

[0078] According to the present example, since the torque of the drive capstan 50 in the wire drawing unit 40 and also the speed of the drive capstan 98 in the wire drawing unit 90 are both controlled, both the tension and wire speed of the wire metal 10 can be further stabilized during the wire drawing operation.

Operation of Winding Unit 60

[0079] The winding unit 60 winds up the metal wire 10 delivered from the unwinding unit 20 and then drawn in each wire drawing unit 40 such that the metal wire 10 has an approximately constant wire speed. That is, the winding unit controller 160 controls the speed of rotation of the winding motor 180 so that the wire speed of the metal wire 10 supplied to the winding unit 60 is maintained at an approximately constant value.

[0080] In the present embodiment, the winding unit controller 160 controls the speed of rotation of the winding motor 180, for example, by using the speed of rotation of, i.e., the wire speed of the metal wire 10 in, the drive capstan 98 which is located before the winding unit 60 as a feed-forward signal and the pivot angle of the dancer arm 76 as a feedback signal. More specifically, the wire speed of the metal wire 10 passing through the drive capstan 98 is detected by an encoder provided at the drive capstan 98 and is fed to the wire drawing unit controller 140. Then, the winding unit controller 160 generates a speed signal indicative of the detected wire speed as a feed-forward signal and supplies it to the winding motor 180 to control the rotation of the winding motor 180.

[0081] Further, the winding unit controller 160 generates a feedback signal based on the pivot angle detected by the potentiometer 178 and controls the rotation of the winding motor 180.

[0082] To be more specific, the winding unit controller 160 calculates a pivot angle deviation between the pivot angle of the dancer arm 76 detected by the potentiometer 178 and the pivot angle of the dancer arm 76 at the reference position. Then, the winding unit controller 160 determines the rotation speed of the winding motor 180 so as to approximate the pivot angle deviation to zero, and provides a rotation speed command to the winding motor 180 based on that determination. Using the pivot angle deviation as a feedback signal, the winding unit controller 160 controls the rotation speed of the winding motor 180 through P control, PI control, PID control, etc.

[0083] With the above operation, the winding unit 60 can maintain the wire speed of the metal wire 10 delivered from the wire drawing unit 40-n (in other words, the wire speed of the metal wire 10 in the drive capstan 98) at an approximately constant value regardless of the amount of metal wire 10 already wound around the winding bobbin 80, and at the same time, wind up the metal wire 10 around the winding bobbin 80 so that there is no gap between the above wire speed and the wire speed of the metal wire 10 passing through the guide rollers 68 and 70.

[0084] According to the operations described above, the wire drawing machine 100 can draw the metal wire 10 wound around the unwinding bobbin 22 in the wire drawing units 40 and 90 and wind up the resulting wire around the winding bobbin 80. For example, if the wire drawing machine 100 has five stages of wire drawing units 40 (i.e., n=5), the metal wire 10 wound around the unwinding bobbin 22 is a piano wire having a diameter of 120 μm and the five wire drawing dies 42 have die hole diameters of 111 μm, 102 μm, 94 μm, 87 μm and 80 μm, respectively, the metal wire 10 wound around the winding bobbin 80 will have a diameter of 80 μm.

Second Example

[0085] In the second example, values of the front tension of the metal wire 10 measured when rotating the drive capstan 50 of each wire drawing unit 40 at a controlled speed (such values will hereinafter be referred to as "sample values") are obtained in advance and, based on the obtained values, the drive capstan 50 is rotated at a controlled torque, instead of a controlled speed, so as to pull out and draw the metal wire 10 through the wire drawing die 42.

[0086] Before performing the wire drawing operation in the wire drawing machine 100, the metal wire 10 is first provided in each wire drawing unit 40 in a tensioned state. In this example, in each wire drawing unit 40, the tip of the metal wire 10 is processed so as to be thin and allowed to pass through the die hole of the wire drawing die 42. After that, the metal wire 10 is pulled through the wire drawing die 42 by rotating the drive capstan 50 at a controlled speed and a predetermined length of metal wire 10 is wound around the drive capstan 50 (this operation will hereinafter be referred to as a "setting operation"). In this example, the wire drawing operation is performed by using the front tension of the metal wire 10 obtained when pulling the metal wire 10 through the wire drawing die 42 at a controlled speed in such setting operation, as a sample value FT' of the front tension.

Operation in Setting operation

[0087] In this example, the metal wire 10 is first provided in the unwinding unit 20 in a tensioned state and, after that, the metal wire 10 is provided in the guide roller 44-1, the wire drawing die 42-1 and the guide roller 46-1 of the wire drawing unit 40-1 in a tensioned state. Then, the wire drawing unit controller 140 rotates the drive capstan 50-1 at a

controlled speed of an approximately constant value, so as to wind a predetermined length of metal wire 10 around the drive capstan 50-1 (or wind the metal wire 10 for a predetermined period of time). Here, the wire drawing unit controller 140 stores the front tension FT1 of the metal wire 10 detected by the distortion gauge 156 provided at the guide roller 46 as a sample value FT1' of the front tension FT1. FT1' may be an instantaneous value of the front tension FT1 or may alternatively be an average value.

[0088] In the wire drawing units 40-2 and 3 as well, the wire drawing unit controller 140 obtains and stores sample values FT2' and FT3' of the front tensions FT2 and FT3 of the metal wire 10 in the same manner.

[0089] Next, the operation of the wire drawing machine 100 drawing the metal wire 10 in this example will be described. Note that since the unwinding unit 20, the wire drawing unit 90 and the winding unit 60 in this example operate in the same manner as in the first example, the following description will be made with regard to the operation of the wire drawing unit 40.

Operation of Wire Drawing Unit 40

[0090] The first-stage wire drawing unit 40-1 draws the metal wire 10 by controlling the rotation torque CT1 of the drive capstan 50-1 based on the sample value FT1' of the front tension FT1, obtained in advance. In this example, FT1' is a sample value obtained in a state where the back tension set value BT1 is applied to the metal wire 10. Accordingly, a sample value DT1' of the drawing force of the wire drawing die 42-1 can be calculated by the following:

$$DT1'=FT1'-BT1$$

[0091] The rotation torque CT1 of the drive capstan 50-1 has the following relationship with the front tension FT1 of the metal wire 10 passing through the wire drawing die 42-1 and the back tension BT2 of the metal wire 10 passing through the wire drawing die 42-2 of the second-stage wire drawing unit 40-2:

$$CT1=FT1-BT2$$

[0092] Further, the front tension FT1, the back tension BT1 and the drawing force DT1 have the following relationship:

$$FT1=BT1+DT1$$

[0093] Thus, the rotation torque CT1 of the drive capstan 50-1 in this example can be obtained, based on the back tensions BT1 and BT2 (both being set values) and the drawing force DT1' (sample value), as follows:

$$CT1=BT1+DT1'-BT2$$

[0094] In this example, the wire drawing unit controller 140 feed-forward controls the rotation torque CT1 of the drive capstan 50-1 using the above formula, so that the back tension BT2 will be a predetermined value based on the back tension set value BT1 and the drawing force sample value DT1', obtained in advance. As a result, the metal wire 10 is pulled through the wire drawing die 42-1 by the drive capstan 50-1 with a pulling force of FT1' in a non-slip manner. Further, the metal wire 10 is, as a setting, delivered to the wire drawing unit 40-2 in a non-slip manner with the back tension BT2 being applied.

[0095] Similarly to the first stage wire drawing unit 40-1, the second stage wire drawing unit 40-2 feed-forward controls the rotation torque CT2 of the drive capstan 50-2 using the below formula, so that the back tension BT3 will be a predetermined value based on the back tension set value BT2 and the drawing force sample value DT2', obtained in advance.

$$CT2=BT2+DT2'-BT3$$

[0096] Likewise, the wire drawing unit controller 140 feed-forward controls the rotation torque CTi of the drive capstan 50i in the i-th stage using the below formula, so that the back tension BTi+1 will be a predetermined value based on the i-th stage back tension set value BTi and the i-th stage drawing force sample value DTi', obtained in advance.

$$CT(i)=BT(i)+DT(i)'-BT(i+1)$$

[0097] As a result, the metal wire 10 is pulled through the wire drawing die 42i by the drive capstan 50i with a pulling force of FTi', in a non-slip manner. Further, the metal wire 10 is, as a setting, delivered to the wire drawing unit 40i+1 (or wire drawing unit 90) in a non-slip manner with the back tension BTi+1 being applied. In the above formula, if i=n, then BTi+1 is regarded as representing the back tension of the metal wire 10 to be drawn by the wire drawing die 92 of the wire drawing unit 90.

[0098] In this example, DT1' is a drawing force sample value in the wire drawing operation. In other words, the drawing force is not actually measured in the wire drawing operation. Thus, even if the metal wire 10 wound around the drive capstan 50 comes loose, DT1' does not vary. Accordingly, in this example, it is preferable for the wire drawing machine 100 to further include a structure to press the metal wire 10 wound around the drive capstan 50 toward that drive capstan 50. Such structure for pressing may be, for example, a roller.

[0099] Further, although, in this example, the front tension values in the setting operation are obtained as sample values, the way of obtaining sample values is not limited thereto.

[0100] According to this example, since the rotation torque CT of the drive capstan 50 is controlled using sample values and any structure for actually measuring a front tension or back tension, etc., in the wire drawing operation is not necessary, a wire drawing machine with a simple configuration can be provided. In addition, according to this example, since the rotation torque CT of the drive capstan 50 is controlled using sample values and the rotation torque CT of the drive capstan 50 does not vary with disturbance, a wire drawing machine achieving stable operation can be provided.

Third Example

[0101] In addition to the second example, the back tension BT of the metal wire 10 is measured in the third example. In this example, the rotation torque of the drive capstan 50 at a particular stage is feed-forward controlled based on the front tension FT of the particular stage and the back tension BT of the next stage. Further, in this example, a feedback control is also performed so that the measured back tension BT will be a predetermined value.

[0102] Hereinafter, the operation of the wire drawing machine 100 drawing the metal wire 10 in this example will be described. Note that since the unwinding unit 20, the wire drawing unit 90 and the winding unit 60 in this example operate in the same manner as those in the first example and since the sample values are obtained in the same manner as those in the second example, the below description will only be made about the operation of the wire drawing unit 40 during the wire drawing operation.

Operation of Wire Drawing Unit 40

[0103] The first-stage wire drawing unit 40-1 draws the metal wire 10 by controlling the rotation torque CT1 of the drive capstan 50-1 based on the sample value FT1' of the front tension FT1, obtained in advance. In this example, FT1' is a sample value obtained in a state where the back tension measurement value BT1' is applied to the metal wire 10. Accordingly, a sample value DT1' of the drawing force of the wire drawing die 42-1 can be calculated based on the following:

$$DT1' \text{ (sample value)}=FT1' \text{ (sample value)}-BT1' \text{ (measurement value)}$$

[0104] The rotation torque CT1 of the drive capstan 50-1 has the following relationship with the front tension FT1 of the metal wire 10 passing through the wire drawing die 42-1 and the back tension BT2 of the metal wire 10 passing

through the wire drawing die 42-2 of the second-stage wire drawing unit 40-2:

$$CT1=FT1-BT2$$

[0105] The wire drawing unit controller 140 feedback controls the rotation torque CT1 of the drive capstan 50-1 based on the above formula. That is, the wire drawing unit controller 140 controls the rotation torque CT1 of the drive capstan 50-1 so as to approximate the measurement value of the back tension BT2 to the set value.

[0106] Further, the front tension FT1, the back tension BT1 and the drawing force DT1 have the following relationship:

$$FT1=BT1+DT1$$

[0107] In this example, the rotation torque of the drive capstan 50-1 is also controlled in a feed-forward manner, and the amount of such feed-forward CT1' can be obtained, based on the back tensions BT1 and BT2 (both being set values) and the drawing force DT1' (sample value), as follows:

$$CT1'=BT1\ (set\ value)+DT1'\ (sample\ value)-BT2\ (set\ value)$$

[0108] In this example, the wire drawing unit controller 140 feed-forward controls the rotation torque CT1 of the drive capstan 50-1 using the above formula, so that the back tension BT2 will be a predetermined value based on the back tension set value BT1 and the drawing force sample value DT1', obtained in advance. As a result, the metal wire 10 is pulled through the wire drawing die 42-1 by the drive capstan 50-1 with a pulling force of FT1' in a non-slip manner. Further, the metal wire 10 is, as a setting, delivered to the wire drawing unit 40-2 in a non-slip manner with the back tension BT2 being applied.

[0109] Similarly to the first stage wire drawing unit 40-1, the second stage wire drawing unit 40-2 feed-forward controls the rotation torque CT2 of the drive capstan 50-2 using the below formula, so that the back tension BT3 will be a predetermined value based on the back tension set value BT2 and the drawing force sample value DT2', obtained in advance.

$$CT2=BT2+DT2'-BT3$$

[0110] Likewise, the wire drawing unit controller 140 feed-forward controls the rotation torque CTi of the drive capstan 50i in the i-th stage using the below formula, so that the back tension BTi+1 will be a predetermined value based on the i-th stage back tension set value BTi and the i-th stage drawing force sample value DTi', obtained in advance.

$$CT(i)=BT(i)+DT(i)'-BT(i+1)$$

[0111] As a result, the metal wire 10 is pulled through the wire drawing die 42i by the drive capstan 50i with a pulling force of FTi', in a non-slip manner. Further, the metal wire 10 is, as a setting, delivered to the wire drawing unit 40i+1 (or wire drawing unit 90) in a non-slip manner with the back tension BTi+1 being applied. In the above formula, if i=n, then BTi+1 is regarded as representing the back tension of the metal wire 10 to be drawn by the wire drawing die 92 of the wire drawing unit 90.

[0112] According to this example, since the back tension of the metal wire 10 is feedback controlled, the difference between the sample value and the actual value of the drawing force or front tension can be prevented from being transferred to the back tension in the next stage and consequently being accumulated, as is the case with the first example. Further, since the back tension is measured in this example, the drawing force of the wire drawing die 42 can

be calculated based on the measured back tension and the rotation torque of the drive capstan 50.

[0113] According to the wire drawing machine and wire drawing method described in the foregoing, since there is no need to provide a dancer in the wire drawing unit, the configuration can be simplified. Further, it becomes possible to provide a wire drawing machine capable of arbitrarily adjusting the conditions of wire drawing, such as arbitrarily setting the back tension or reduction in area of the metal wire. Thus, the wire drawing machine and wire drawing method of the present embodiment can bring about excellent effects, including arbitrarily setting the back tension so that deterioration of the wire drawing die can be reduced and arbitrarily setting the reduction in area so that the number of wire drawing dies used can be reduced. Furthermore, according to the wire drawing machine and wire drawing method of the present embodiment, since the wire drawing conditions, such as the wire drawing speed, back tension, front tension, etc., can be arbitrarily adjusted, it is possible to produce metal wires having various properties in terms of wire diameter, curl diameter, etc., and metal wires having excellent properties in terms of breaking force, tension strength, etc., compared to conventional wires.

[0114] The examples and applications described above through the embodiments of the invention can be combined as appropriate depending on the intended purpose of use, or used by making various modifications or improvements, and the invention is not limited to the above-described embodiments. It will be apparent from the description of the attached claims that such combinations or embodiments in which such modifications or improvements are made can also fall within the technical scope of the invention.

Description of Reference Numerals

[0115]

10 ... metal wire; 11 ... metal wire; 20 ... unwinding unit; 22 ... unwinding bobbin; 22 ... unwinding motor; 24, 26, 28 ... guide roller; 32 ... dancer section; 34 ... dancer roller; 36 ... dancer arm; 38 ... torque motor; 40 ... wire drawing unit; 42 ... wire drawing die; 44, 46 ... guide roller; 50 ... drive capstan; 60 ... winding unit; 66, 68, 70 ... guide roller; 72 ... dancer section; 74 ... dancer roller; 76 ... dancer arm; 78 ... torque motor; 80 ... winding bobbin; 92 ... wire drawing die; 94, 96 ... guide roller; 98 ... drive capstan; 100 ... wire drawing machine; 110 ... system controller; 120 ... unwinding unit controller; 122 ... unwinding motor; 138 ... potentiometer; 140 ... wire drawing unit controller; 150 ... drive motor; 152, 156 ... distortion gauge; 154, 158 ... encoder; 160 ... winding unit controller; 178 ... potentiometer; 180 ... winding motor; 200 ... control unit; BT ... back tension; CT ... rotation torque; DT ... drawing force; and FT ... front tension.

Claims

1. A wire drawing machine comprising:

a first wire drawing die for reducing a diameter of a metal wire passing therethrough, thereby drawing the metal wire;
a back tension control unit that controls a first back tension of the metal wire passing through the first wire drawing die;
a first capstan that pulls the metal wire passing through the first wire drawing die at a first front tension through the first wire drawing die in a non-slip manner;
a first front tension measuring unit that measures the first front tension;
a first capstan control unit that controls a rotation torque of the first capstan based on the measured first front tension; and
a winding unit that winds up the drawn metal wire.

2. The wire drawing machine of claim 1, further comprising a second wire drawing die which is provided between the first capstan and the winding unit and through which the metal wire pulled out by the first capstan passes, so as to reduce the diameter of the metal wire passing therethrough, thereby drawing the metal wire,
wherein the first capstan delivers the metal wire to the second wire drawing die in a non-slip manner, and
wherein the first capstan control unit controls the rotation torque of the first capstan based on the first front tension so that the metal wire passing through the second wire drawing die has a second back tension of a predetermined value.

3. The wire drawing machine of claim 2, further comprising:

a second capstan that pulls the metal wire passing through the second wire drawing die at a second front tension through the second wire drawing die in a non-slip manner;
a third wire drawing die which is provided between the second capstan and the winding unit and through which the metal wire pulled out by the second capstan passes, so as to reduce the diameter of the metal wire passing therethrough, thereby drawing the metal wire;
a second front tension measuring unit that measures the second front tension; and
a second capstan control unit that controls a rotation torque of the second capstan based on the measured second front tension,
wherein the second capstan control unit controls the rotation torque of the second capstan based on the second front tension so that the metal wire passing through the third wire drawing die has a third back tension of a predetermined value.

4. The wire drawing machine of claim 1, further comprising an unwinding unit that delivers the metal wire to the first wire drawing die,
wherein the back tension control unit is a dancer that controls the first back tension of the metal wire between the unwinding unit and the first wire drawing die.

5. A wire drawing machine comprising:

a first wire drawing die for reducing a diameter of a metal wire passing therethrough, thereby drawing the metal wire;
a back tension control unit that controls a first back tension of the metal wire passing through the first wire drawing die;
a first capstan that pulls the metal wire passing through the first wire drawing die in a non-slip manner through the first wire drawing die;
a first capstan control unit that controls a rotation torque of the first capstan so as to pull the metal wire through the first wire drawing die; and
a winding unit that winds up the drawn metal wire,
wherein the first capstan control unit stores, in advance, a first front tension of the metal wire obtained when pulling the metal wire through the first wire drawing die by rotating the first capstan at a controlled speed, and
wherein the first capstan control unit controls the rotation torque of the first capstan based on the first front tension so as to pull the metal wire through the first wire drawing die.

6. The wire drawing machine of claim 5, wherein the first capstan control unit stores, as the first front tension, an average torque of the first capstan obtained when pulling the metal wire through the first wire drawing die by rotating the first capstan at a controlled speed for a predetermined period of time.

7. The wire drawing machine of claim 5, further comprising:

a second wire drawing die which is provided between the first capstan and the winding unit and through which the metal wire pulled out by the first capstan passes, so as to reduce the diameter of the metal wire passing therethrough, thereby drawing the metal wire; and
a back tension measuring unit that measures a second back tension of the metal wire passing through the second wire drawing die,
wherein the first capstan delivers the metal wire to the second wire drawing die in a non-slip manner, and
wherein the first capstan control unit controls the rotation torque of the first capstan so that the measured second back tension becomes a predetermined value.

8. A wire drawing method for drawing a metal wire by causing the metal wire to pass through a wire drawing die so as to reduce a diameter of the metal wire, the method comprising the steps of:

controlling a back tension of the metal wire passing through the wire drawing die;
pulling the metal wire passing through the wire drawing die at a predetermined front tension through the wire drawing die in a non-slip manner using a capstan;
measuring the front tension; and
controlling a rotation torque of the capstan based on the measured front tension.

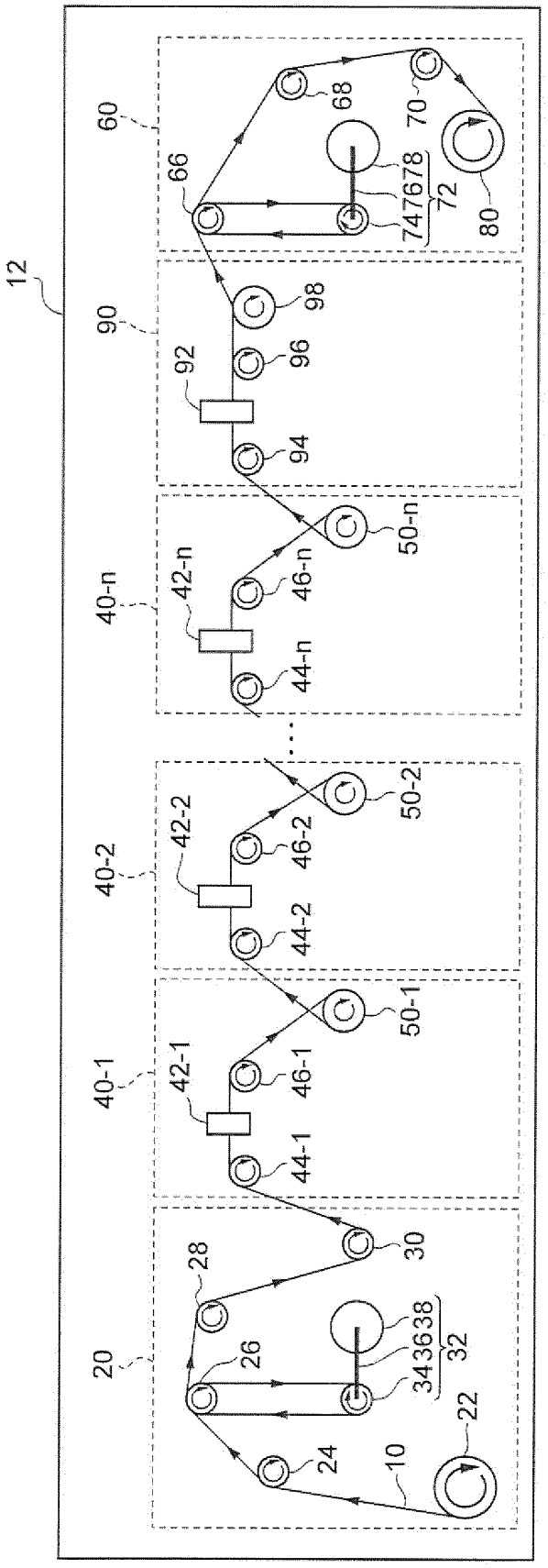
9. A wire drawing method for drawing a metal wire by causing the metal wire to pass through a wire drawing die so as

to reduce a diameter of the metal wire, the method comprising:

a step of controlling a back tension of the metal wire passing through the wire drawing die;
a step of pulling the metal wire passing through the wire drawing die in a non-slip manner through the wire drawing die using a capstan; and
a controlling step of controlling a rotation torque of the capstan,
wherein the controlling step comprises the steps of:

storing, in advance, a front tension of the metal wire obtained when pulling the metal wire through the wire drawing die by rotating the capstan at a controlled speed;and
controlling the rotation torque of the capstan based on the front tension so as to pull the metal wire through the wire drawing die.

FIG. 1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96
98

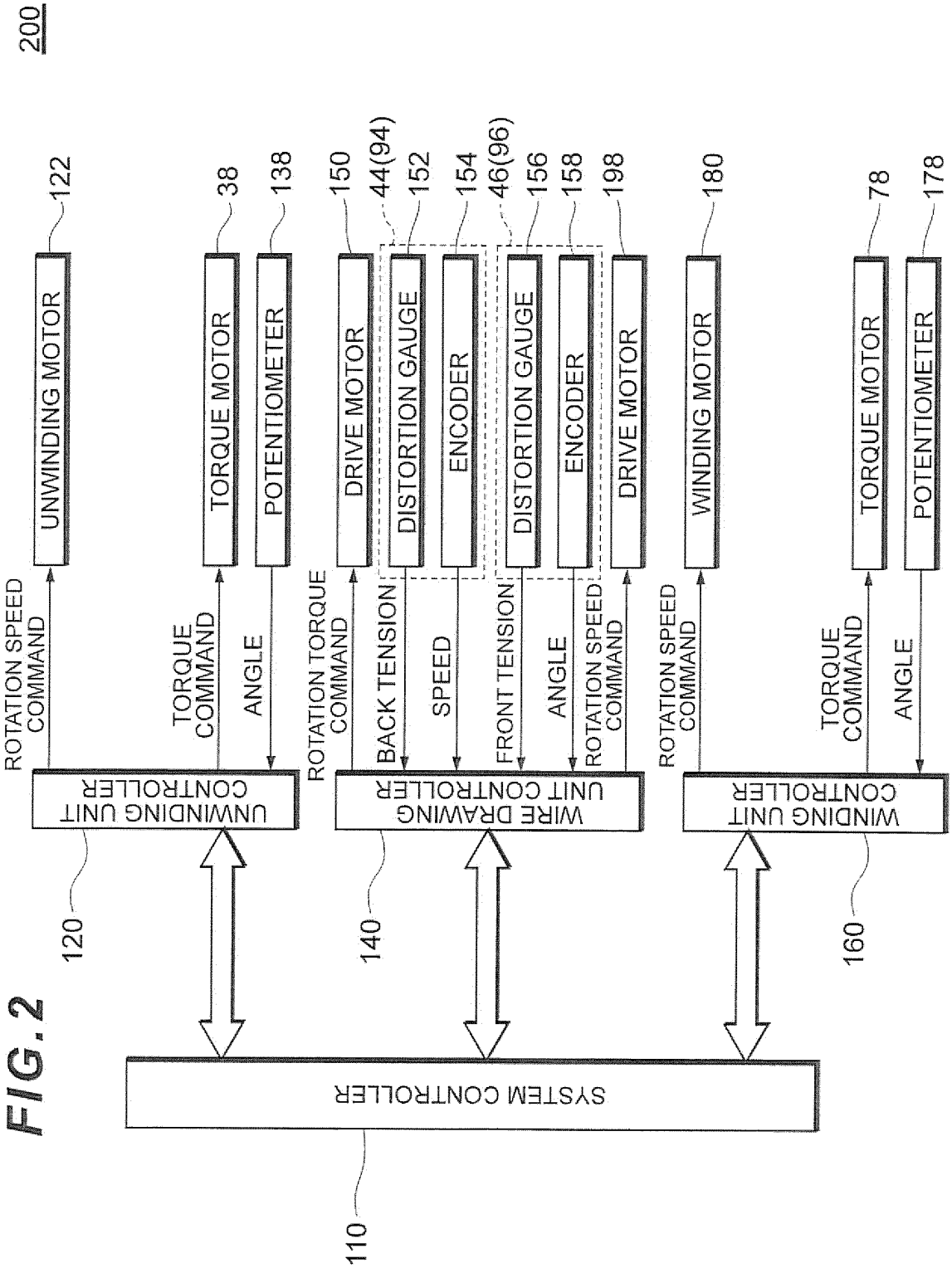
200
122
UNWINDING MOTOR
38
TORQUE MOTOR
138
POTENTIOMETER
150
DRIVE MOTOR
44(94)
152
DISTORTION GAUGE
154
ENCODER
46(96)
156
DISTORTION GAUGE
158
ENCODER
198
DRIVE MOTOR
180
WINDING MOTOR
78
TORQUE MOTOR
178
POTENTIOMETER
ROTATION SPEED COMMAND
TORQUE COMMAND
ANGLE
ROTATION TORQUE COMMAND
BACK TENSION
SPEED
FRONT TENSION
ANGLE
ROTATION SPEED COMMAND
ROTATION SPEED COMMAND
TORQUE COMMAND
ANGLE
UNWINDING UNIT CONTROLLER
WIRE DRAWING UNIT CONTROLLER
WINDING UNIT CONTROLLER
120
140
160
SYSTEM CONTROLLER
110

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/074083

A. CLASSIFICATION OF SUBJECT MATTER
B21C1/12(2006.01)i, *B21C1/08*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B21C1/12, B21C1/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2012
Kokai Jitsuyo Shinan Koho 1971-2012 Toroku Jitsuyo Shinan Koho 1994-2012

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 8-24939 A (Marusan Kikai Co., Ltd.), 30 January 1996 (30.01.1996), paragraphs [0002] to [0006]; fig. 1 (Family: none)	1-4,8
Y	JP 2005-103623 A (Yugen Kaisha FA Denshi), 21 April 2005 (21.04.2005), paragraphs [0064] to [0065], [0087] (Family: none)	1-4,8
Y	JP 60-162519 A (Gosudarusutouennui), 24 August 1985 (24.08.1985), page 4, upper right column (Family: none)	1-4,8

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 December, 2012 (04.12.12)	18 December, 2012 (18.12.12)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/074083

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2000-33413 A (Maschinenfabrik Niehoff GmbH & Co. KG), 02 February 2000 (02.02.2000), entire text & US 6116068 A & EP 965394 A1 & DE 59801770 D & BR 9901598 A & ES 2163822 T & PT 965394 E	1-9

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2003053418 A **[0002] [0003]**