

DESCRIPTION

MANUFACTURING METHOD OF MECHANICAL WATCH

TECHNICAL FIELD

The present invention relates to a manufacturing method of a mechanical watch.

Specifically, the present invention relates to a mechanical watch manufacturing method which enables to manufacture a high precision mechanical watch by accurately controlling the rate of the mechanical watch by adjusting the effective length of a hair spring of a balance by prolonging or shortening the length of the hair spring by using a piezoelectric element in a movement of the mechanical watch.

BACKGROUND OF THE INVENTION

As shown in FIGs. 10 and 11, a movement (mechanical body) 1100 of a prior art mechanical watch has a main plate 1102 which forms of a substrate of the movement. A winding stem 1110 is rotably assembled to a winding stem guide hole 1102a of the main plate 1102. A dial 1104 (indicated by imaginary lines in FIG. 11) is mounted to the movement 1100.

Among the both sides of the main plate, the side where the dial is located will be called as "back side" and the side opposite from the side where the dial is located will be called as "front side" in general. A wheel train assembled on the

"front side" of the movement will be called as a "front wheel train" and a wheel train assembled on the "back side" of the movement will be called as a "back wheel train".

The position of the winding stem 1110 in the axial direction is determined by a switch comprising a setting lever 1190, a yoke 1192, a yoke spring 1194 and a setting lever jumper 1196. A winding pinion 1112 is rotably provided at the guide axis section of the winding stem 1110. When the winding stem 1110 is rotated when the winding stem 1110 is located at the first winding stem position (0 stage) where it is closest to the inside of the movement along the rotational axis direction, the winding pinion 1112 rotates as a clutch wheel rotates. Then, a crown wheel 1114 rotates as the winding pinion 1112 rotates. A ratchet wheel 1116 also rotates as the crown wheel 1114 rotates. A main spring 1122 stored in a movement barrel 1120 is wound up as the ratchet wheel 1116 rotates. A center wheel & pinion 1124 rotates as the movement barrel 1120 rotates. An escape wheel & pinion 1130 rotates as a fourth wheel & pinion 1128, a third wheel & pinion 1126 and the center wheel & pinion 1124 rotate. The movement barrel 1120, the center wheel & pinion 1124, the third wheel & pinion 1126 and the fourth wheel & pinion 1128 compose the front wheel train.

An escape and governor for controlling the rotation of the front wheel train comprises a balance 1140, the escape wheel & pinion 1130 and an pallet fork 1142. The balance 1140

comprises a balance stem 1140a, a balance wheel 1140b and a hair spring 1140c. An cannon pinion 1150 rotates in the same time with the rotation of the center wheel & pinion 1124. A minute hand 1152 mounted to the cannon pinion 1150 indicates "minute". The cannon pinion 1150 is provided with a slip mechanism for the center wheel & pinion 1124. An hour wheel 1154 rotates via the rotation of a minute wheel based on the rotation of the cannon pinion 1150. An hour hand mounted to the hour wheel 1154 indicates "hour".

The movement barrel 1120 is rotably supported with respect to the main plate 1102 and a barrel bridge 1160. The center wheel & pinion 1124, the third wheel 1126, the fourth wheel 1128 and the escape wheel & pinion 1130 are rotably supported with respect to the main plate 1102 and a train wheel bridge 1162. The pallet fork 1142 is rotably supported with respect to the main plate 1102 and an pallet fork bridge 1164. The balance 1140 is rotably supported with respect to the balance 1102 and a balance bridge 1166.

The hair spring 1140c is a spiral thin plate spring having a plurality of number of turns. The inner edge of the hair spring 1140c is fixed to a hair spring ball 1140d fixed to the balance stem 1140a and the outer edge of the hair spring 1140c is fixed by a screw via a stud support 1170a fixed to a hair spring bridge 1170 which is fixed to the balance bridge 1166.

A regulator 1168 is rotably mounted to the balance bridge 1166. The hair spring bridge 1168a and a hair spring bar 1168b are attached to the regulator 1168. The portion of the hair spring 1140c closed to the outer edge thereof is located between the hair spring bridge 1168a and the hair spring bar 1168b.

Torque of the main spring of the typical conventional mechanical watch decreases as the main spring is unwound from the state in which the main spring has been wound up completely (total wind-up state) and as the duration elapses in general. For instance, while the torque of the spring is about 27 g • cm in the total wind-up state, it becomes about 23 g • cm when 20 hours elapses from the total wind-up state and becomes about 18 g • cm when 40 hours elapses from the total wind-up state.

When the torque of the spring decreases, an angle of swing of the balance also decreases in general in the typical conventional mechanical watch. For instance, the angle of swing of the balance is about 240 to 270 degrees when the spring torque is 25 to 28 g • cm and the swing angle of the balance becomes about 180 to 240 degrees when the spring torque is 20 to 25 g • cm.

Here, "instantaneous rate" or "rate" means "a value indicating an advancement or delay of the mechanical watch when one day elapses when the mechanical watch is supposedly

left alone one day while maintaining the conditions such as the swing angle of the balance and the environment when the rate was measured". The "rate" is denoted by H .

For instance, although the instantaneous rate is about 0 to 5 seconds/day (advance by about 0 to 5 seconds per day) when the swing angle of the balance is about 200 to 240 degrees in the typical conventional mechanical watch, the instantaneous rate becomes about -20 seconds/day (delay by about 20 seconds per day) when the swing angle of the balance is about 170 degrees.

The instantaneous rate delays in general in the conventional mechanical watch because the spring torque decreases and the swing angle of the balance also decreases as the spring is unwound from the total wind-up state and as the duration elapses. Therefore, considering the delay of the watch after the elapse of the duration of 24 hours, the conventional mechanical watch has been adjusted so that the "rate" which indicates the advancement or delay of the watch per day becomes plus by advancing the instantaneous rate when the spring is totally wind up in advance.

Assuming the state in which the dial is mounted, "horizontal position" in which the dial becomes horizontal and "vertical position" in which the dial becomes vertical may be defined in the mechanical watch.

Further, assuming the state in which the dial is mounted

in the mechanical watch, the direction of heading to the 12 o'clock indicator of the dial from the center of the mechanical watch is called "12 o'clock direction", the direction of heading to the 3 o'clock indicator of the dial from the center of the mechanical watch is called "3 o'clock direction" the direction of heading to the 6 o'clock indicator of the dial from the center of the mechanical watch is called "6 o'clock direction" and the direction of heading to the 9 o'clock indicator of the dial from the center of the mechanical watch is called "9 o'clock direction" (see FIG. 9).

Still more, assuming the state in which the dial is mounted vertically in the mechanical watch, the position in which the 12 o'clock indicator of the dial comes to the top is called as "position on the 12 o'clock", the position in which the 3 o'clock indicator of the dial comes to the top is called as "position on the 3 o'clock", the position in which the 6 o'clock indicator of the dial comes to the top is called as "position on the 6 o'clock" and the position in which the 9 o'clock indicator of the dial comes to the top is called as "position on the 9 o'clock".

Then, it has been known that measured values of the "rate" differ in the four positions of "the position on 12 o'clock", "the position on 3 o'clock", "the position on 6 o'clock" and "the position on 9 o'clock" in the mechanical watch. Accordingly, the rate of the mechanical watch has been

adjusted in manufacturing the mechanical watch by measuring the "rate" for these four positions so that the measured values of the respective "rates" meet with predetermined standard.

In the explanation below, "the rate when the mechanical watch is set at the position of the 12 o'clock" will be called as "rate on 12", the rate when the mechanical watch is set at the position of the 3 o'clock" will be called as "rate on 3", "the rate when the mechanical watch is set at the position of the 6 o'clock" will be called as "rate on 6" and the rate when the mechanical watch is set at the position of the 9 o'clock" will be called as "rate on 9".

Hitherto, the rate of such mechanical watch has been adjusted by manually removing the balance 1140 from the movement (mechanical body) 1100 of the mechanical watch once assembled, by manually cutting a portion of the balance wheel and by assembling the balance 1140 to the movement (mechanical body) 1100 again. To that end, the rate has been measured in the movement (mechanical body) 1100 of the mechanical watch once assembled at first and then the rate has been measured in the movement (mechanical body) 1100 in which the balance 1140 is reassembled after cutting the portion of the balance wheel.

Accordingly, the balance 1140 had to be decomposed and assembled again in adjusting the rate in the conventional manufacturing method of the mechanical watch. Therefore,

there has been a problem in the manufacturing method of the mechanical watch that it takes a lot of time and works in adjusting the rate because the rate adjusting work is complicated and the rate measuring work is complicated.

Beside that, it has been difficult to adjust the rate at high precision because the adjustment of the rate in the conventional manufacturing method of the mechanical watch includes the step of manually cutting the portion of the balance wheel.

Accordingly, it is an object of the present invention to provide a mechanical watch manufacturing method which allows the rate of the mechanical watch to be adjusted without removing the balance from the movement (mechanical body) of the mechanical watch.

It is another object of the invention to provide a mechanical watch manufacturing method which allows the rate of the mechanical watch to be adjusted at very high precision.

DISCLOSURE OF THE INVENTION

The present invention relates to a manufacturing method of a mechanical watch comprising a movement having a spring composing a power source of the mechanical watch, a front wheel train which rotates by rotational force which arises when the spring is unwound and an escape and governor for controlling the rotation of the front wheel train. The

escape and governor comprises a balance which repeats right and left turns alternately, an escape wheel & pinion which rotates based on the rotation of the front wheel train and a pallet fork which controls the rotation of the escape wheel & pinion based on the operation of the balance. The balance comprises a hair spring, a balance stem and a balance wheel.

The inventive mechanical watch manufacturing method comprises:

(a) a step of assembling the movement of the mechanical watch;

(b) a step of measuring the rates of the assembled movement;

(c) a step of calculating the total adjustment of the balance based on the result of measurement of the rates in the previous step (b);

(d) a step of calculating the oscillating length of the hair spring to be adjusted based on the result of calculation of the total adjustment of the balance in the previous step (c); and

(e) a step of adjusting the oscillating effective length of the hair spring by oscillating a hair spring controlling piezoelectric element which is disposed in contact with the hair spring based on the result of calculation of the length of the hair spring in the previous step (d) to be adjusted.

In the inventive mechanical watch manufacturing method, preferably the measurement of the rate in the step (b) is carried out on four "vertical positions" of "position on 12 o'clock", "position on 3 o'clock", "position on 6 o'clock" and "position on 9 o'clock".

Still more, in the inventive mechanical watch manufacturing method, the measurement of the rate in the step (b) is preferably carried out by measuring the operation of the balance while winding up the spring by using a balance operation measuring apparatus and the balance operation measuring apparatus measures the operation of the balance by receiving light emitted from a light source disposed so as to illuminate a balance arm by two light receiving sections.

Further, in the inventive mechanical watch manufacturing method, the balance operation measuring apparatus stores the relationship between the period of light entering the light receiving sections and a swing angle of the balance in advance and calculates the swing angle of the balance by using the period of light entering the light receiving sections.

Still more, in the inventive mechanical watch manufacturing method, the movement of the mechanical watch comprises a piezoelectric element lead substrate which is provided with first and second patterns and a pulse for driving a hair spring controlling piezoelectric element is outputted

from a piezoelectric element driving apparatus to the first and second patterns.

Still more, in the inventive mechanical watch manufacturing method, preferably the piezoelectric element lead substrate is fastened to the main plate by using a substrate screw after adjusting the rate of the mechanical watch by the step (e) to short the first pattern with the second pattern of the piezoelectric element lead substrate.

The use of the inventive method allows the rate of the mechanical watch to be very simply adjusted without removing the balance out of the movement of the mechanical watch.

Still more, the use of the inventive mechanical watch manufacturing method allows the rate of the mechanical watch to be adjusted in a short time and at very high precision.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view schematically showing the front side of a movement of a mechanical watch manufactured by using the inventive mechanical watch manufacturing method (parts of the portion thereof is omitted and plate members are indicated by imaginary lines).

FIG. 2 is an enlarged partial section view showing a balance bridge and balance wheel part before adjusting the rate in the movement of the mechanical watch manufactured by using the inventive mechanical watch manufacturing method.

FIG. 3 is a partial section view showing the movement of the mechanical watch manufactured by using the inventive mechanical watch manufacturing method.

FIG. 4 is a partial section view showing the states in manufacturing the movement of the mechanical watch by using the inventive mechanical watch manufacturing method.

FIG. 5 is a flowchart outlining steps in adjusting the rate in the inventive mechanical watch manufacturing method.

FIG. 6 is a flowchart detailing the steps in adjusting the rate in the inventive mechanical watch manufacturing method.

FIG. 7 is a graph outlining the relationship between angles of swing of a balance before adjusting the rate and the rates in four positions in the mechanical watch to be manufactured by using the inventive mechanical watch manufacturing method.

FIG. 8 is a graph outlining the relationship between angles of swing of the balance and the rates in four positions in the mechanical watch in which the rate has been adjusted by using the inventive mechanical watch manufacturing method.

FIG. 9 is a graph detailing the relationship between angles of swing of the balance and the rates in four positions in the mechanical watch in which the rate has been adjusted by using the inventive mechanical watch manufacturing method.

FIG. 10 is a plan view showing the schematic shape of

the front side of the movement of a conventional mechanical watch (parts of the portion thereof is omitted and plate members are shown by imaginary lines in FIG. 10).

FIG. 11 is a schematic partial section view of a movement of the conventional mechanical watch (parts of portions thereof is omitted in FIG. 11).

BEST MODE FOR CARRYING OUT THE INVENTION

An embodiment of the inventive mechanical watch manufacturing method will be explained below based on the drawings.

(1) Movement manufactured by inventive mechanical watch manufacturing method:

In an embodiment of the inventive mechanical watch manufacturing method, a movement (mechanical body) 400 of the mechanical watch is assembled at first as shown in FIGs. 1 through 3.

The movement 100 of the mechanical watch comprises a main plate 102 which forms of the substrate of the movement. A winding stem 110 is rotably assembled to a winding stem guide hole 102a of the main plate 102.

A dial 104 (shown by an imaginary line in FIG. 3) is mounted to the movement 100 after adjusting the rate by using the inventive mechanical watch manufacturing method. The dial 104 is provided with a 12 o'clock indicator, a 3 o'clock

indicator, a 6 o'clock indicator and a 9 o'clock indicator (no indicator are shown in the figure) for example.

The winding stem 110 has an square section and a guide axis section. A clutch wheel (not shown) is assembled to the square section of the winding stem 110. The clutch wheel has the same rotary axial line with the rotary axial line of the winding stem 110. That is, the clutch wheel has an square hole and rotates based on the rotation of the winding stem 110 by fitting the square section of the winding stem 110 to this square hole. The clutch wheel has A teeth and B teeth. The A teeth are provided at the edge of the clutch wheel closer to the center of the movement and the B teeth are provided at the edge of the clutch wheel closer to the outside.

A switch for deciding the position of the winding stem 110 in the axial direction is inserted to the movement 400. The switch comprises a setting lever 132, a yoke 134, a yoke spring 136 and a setting lever jumper 136. The position of the winding stem 110 in rotary axial direction is determined based on the rotation of the setting lever 132. The position of the clutch wheel in the rotational axial direction is determined based on the rotation of the yoke 134. The yoke 134 is positioned at two positions in the rotational direction based on the rotation of the setting lever 132.

A winding pinion 112 is rotably assembled to the guide axis section of the winding stem 110. When the winding stem

110 is rotated when the winding stem 110 is located at the first winding stem position closest to the inner side of the movement 400 along the rotary axial direction, the winding pinion 112 rotates via the rotation of the clutch wheel. A crown wheel 114 is assembled so as to rotate by the rotation of the winding pinion 112. A ratchet wheel 116 is assembled so as to rotate by the rotation of the crown wheel 114.

The movement 400 uses a spring (not shown) stored in a movement barrel 120 as power source. The spring is made of an elastic member such as iron having a quality of spring. The spring may be wound up by rotating the ratchet wheel 116.

A center wheel & pinion 124 is assembled so as to rotate by the rotation of the movement barrel 120. A third wheel & pinion 126 is assembled so as to rotate based on the rotation of the center wheel & pinion 124. A fourth wheel & pinion 128 is assembled so as to rotate based on the rotation of the third wheel & pinion 126. A escape wheel & pinion 130 is assembled so as to rotate based on the rotation of the fourth wheel & pinion 128. The movement barrel 120, the center wheel & pinion 124, the third wheel & pinion 126 and the fourth wheel & pinion 128 compose the front wheel train.

An escape and governor for controlling the rotation of the front wheel train is assembled to the movement 400. The escape and governor comprises a balance 140 which repeats right and left turns at constant period, the escape wheel &

pinion 130 which rotates based on the rotation of the front wheel train and a pallet fork 142 for controlling the rotation of the escape wheel & pinion 130 based on the operation of the balance 140.

The balance 140 comprises a balance stem 140a, a balance wheel 140b and a hair spring 140c. It is provided with four balance arms 140f (called Amida) for linking the balance stem 140a with the balance wheel 140b. A number of the balance arms 140f may be two, three or more than four.

The hair spring 140c is made of an elastic member having the quality of spring such as "elinver". That is, the hair spring 140c is made of a metallic conductive material.

An cannon pinion (not shown) rotates in the same time with the rotation of the center wheel & pinion 124. The minute hand (not shown) attached to the cannon pinion indicates "minute". The cannon pinion is provided with a slip mechanism having predetermined slip torque to the center wheel & pinion 124.

A minute wheel (not shown) rotates based on the rotation of the cannon pinion. A hour wheel (not shown) rotates based on the rotation of the minute wheel. An hour hand (not shown) attached to the hour wheel indicates "hour".

The movement barrel 120 is rotably supported with respect to the main plate 102 and a barrel bridge 160. The center wheel & pinion 124, the third wheel & pinion 126, the

fourth wheel & pinion 128 and the escape wheel & pinion 130 are rotably supported with respect to the main plate 102 and a train wheel bridge 162. The pallet fork 142 is rotably supported with respect to the main plate 102 and the pallet fork bridge 164.

The balance 140 is rotably supported with respect to the main plate 102 and a balance bridge 166. That is, an upper mortise 140a1 of the balance stem 140a is rotably supported with respect to a balance upper bearing 166a fixed to the balance bridge 166. The balance upper bearing 166a comprises a balance upper hole jewel and balance upper bridge jewel. The balance upper hole jewel and the balance upper bridge jewel are made of insulating material such as ruby.

A balance measuring window 102h for measuring the rotational operation of the balance arm 140f of the balance 140 is provided on the main plate 102. The balance arm 140f rotates as if it crosses the balance measuring window 102h.

An under mortise 140a2 of the balance stem 140a is rotably supported with respect to a balance under bearing 102b fixed to the main plate 102. The balance under bearing 102b comprises a balance lower hole jewel and balance lower bridge jewel. The balance lower hole jewel and the balance lower bridge jewel are made of insulating material such as ruby.

The hair spring 140c is a spiral thin plate spring having a plurality of number of turns. The inner edge of the

hair spring 140c is fixed to a hair spring ball 140d which is in turn fixed to the balance stem 140a.

The hair spring 140c expands in the radial direction of the hair spring 140c in correspondence to a rotational angle of the balance 140. For instance, in the state shown in FIGs. 1 and 2, the hair spring 140c contracts in the direction heading to the center of the balance 140 when the balance 140 rotates clockwise and the hair spring 140c expands in the direction separating from the center of the balance 140 when the balance 140 rotates counterclockwise.

A stud support 430 is fixed to the balance bridge 166. A stud holder 456 is fixed to the stud support 430. A hair spring controlling piezoelectric device 454 is fixed to the stud holder 430. The hair spring controlling piezoelectric element 454 is provided so as to contact with the portion close to the outer edge of the hair spring 140c to move in/out the hair spring 140c in the longitudinal direction.

A hair spring holder spring 452 is provided to press the portion of the hair spring 140c close to the outer edge. Accordingly, the portion of the hair spring 140c close to the outer edge is disposed between the hair spring controlling piezoelectric element 454 and the hair spring holding spring 452. The hair spring holder spring 452 is made of an elastic material such as metal.

A piezoelectric element lead substrate 420 is disposed

on the main plate 102. The piezoelectric element lead substrate 420 has a first pattern 420a and a second pattern 420b. A first lead wire 422 is provided to connect the hair spring controlling piezoelectric element 454 with the first pattern 420a. A second lead wire 424 is provided to connect the hair spring controlling piezoelectric element 454 with the second pattern 420b. In the inventive mechanical watch manufacturing method, a substrate stopping screw 428 fastens the piezoelectric element lead substrate 420 to the main plate 102 as shown in FIG. 3 after adjusting the rate of the mechanical watch. In this state, the first pattern 420a of the piezoelectric element lead substrate 420 shorts with the second pattern 420b thereof.

(2) Rate adjusting step in inventive mechanical watch manufacturing method:

Next, the rate adjusting step in the inventive mechanical watch manufacturing method will be explained.

(2.1) Outline of rate adjusting step of mechanical watch:

An outline of the rate adjusting method of the mechanical watch will be explained below.

In the inventive mechanical watch rate adjusting method, the movement 100 of the mechanical watch is assembled at first as shown in FIG. 7. As described above, the winding stem 110, the crown wheel 114, the winding pinion 112, the

ratchet wheel 116, the crown wheel 114, the switch, the front wheel train, the escape and governor, the cannon pinion, the minute wheel and the hour wheel are assembled so as to be operative with respect to the main plate 102 or the bridge members 160, 162 and 166.

As described above, the escape and governor comprises the balance 140 which alternately repeat right and left turns, the escape wheel & pinion 130 which rotates based on the rotation of the front wheel train and the pallet fork 142 which controls the rotation of the escape wheel & pinion 130 based on the operation of the balance 140. The balance 140 comprises the balance stem 140a, the balance wheel 140b and the hair spring 140c.

Next, the rate of the mechanical watch is measured by measuring the operative condition of the balance 140 in the plurality of positions in the state in which the assembled movement is disposed in the "vertical position".

The rate is measured for four positions of "position on the 12 o'clock", "position on the 3 o'clock", "position on the 6 o'clock", and "position on the 9 o'clock" for example.

Then, the "rate on 12" is measured by setting the mechanical watch at the position on the 12 o'clock, the "rate on 3" is measured by setting the mechanical watch at the position on the 3 o'clock, the "rate on 6" is measured by setting the mechanical watch at the position on the 6 o'clock

and the "rate on 9" is measured by setting the mechanical watch at the position on the 9 o'clock.

Such measurement of the rates may be carried out for two or more plurality of "vertical positions". The measurement of the rate may be carried for positions other than the "position on the 12 o'clock", "position on the 3 o'clock", "position on the 6 o'clock" and "position on the 9 o'clock" such as "position on the 1 o'clock", "position on the 2 o'clock", "position on the 4 o'clock", "position on the 5 o'clock", "position on the 7 o'clock", "position on the 8 o'clock", "position on the 10 o'clock" and "position on the 11 o'clock".

That is, the measurement of the rate may be carried out for the plurality of positions among the 12 "vertical positions" described above.

(2.2) Adjust angle of swing of balance:

The detail content of the mechanical watch rate adjusting steps will be explained below.

The swing angle of the balance is adjusted while disposing the movement of the mechanical watch in the "horizontal position" as shown in FIG. 6 (Step S1 in FIG. 6).

The adjustment of the swing angle of the balance may be carried out by engaging a gear provided on the outside of the movement with the ratchet wheel, by winding up the spring

and by measuring a number of windings of the spring.

Or, the adjustment of the swing angle of the balance may be carried out by measuring the operation of the balance while winding up the spring by using a balance operation measuring device as described later.

A light source 460 for illuminating a balance arm 140f is disposed as shown in FIG. 4. Two light receiving sections 462a and 462b are provided to receive light illuminating the balance arm 140f. The two light receiving sections 462a and 462b are disposed along the rotation direction of the balance, i.e., leaving a gap therebetween at the positions of almost equal distance from the center of rotation of the balance.

Accordingly, the balance arm 140f operates between the light source 460 and the light receiving sections 462a and 462b. When the balance arm 140f is located between the light source 460 and the light receiving section 462, the light illuminated by the light source 460 is blocked by the balance arm 140f and do not enter the light receiving sections 462a and 462b. In contrary to that, when the balance arm 140f is not located between the light source 460 and the light receiving sections 462a and 462b, the light illuminated from the light source 460 enters the light receiving section 462. The light receiving sections 462a and 462b are composed of optical fibers, CCD or diodes for instance.

It is possible to detect the rotational direction of

the balance and the rotational period of the balance by providing the two light receiving sections 462a and 462b in such disposition.

The light receiving sections 462a and 462b are connected with a balance operation measuring apparatus 464. The balance operation measuring apparatus 464 is provided to calculate the rotational direction, the rotational period and the swing angle of the balance 140 by measuring the operation of the balance arm 140f.

The balance operation measuring apparatus 464 stores the relationship between the period of the light entering the light receiving sections 462a and 462b and the swing angle of the balance in advance. Accordingly, the calculation of the swing angle of the balance 140 may be carried out by using the period of the light entering the light receiving sections 462a and 462b.

The swing angle of the balance for measuring the rate in the state disposed in the "horizontal position" may be a plurality of angles. For instance, the balance swing angle includes at least 150 and 250 degrees. The balance swing angle may include other angles such as 160, 180, 200, 220 and 240 degrees for example.

(2.3) Measurement of "rate" for four positions:

The position of the assembled movement is moved before

measuring the "rate" in the inventive method (Step S2 in FIG. 6).

The "rate" is measured for the four positions of the "position on the 12 o'clock", "position on the 3 o'clock", "position on the 6 o'clock" and "position on the 9 o'clock" while disposing the assembled movement in the "vertical position" (Step S3 in FIG. 6).

It is then judged whether or not the step of measuring the "rate" by disposing the assembled movement in all "vertical positions" set in advance has been completed (Step S4 in FIG. 6). When the step of measuring the "rate" has not been completed, the process returns to Step S1 to measure the "rate" by disposing the assembled movement in the next "vertical position". When all of the steps for measuring the "rate" are completed, the process advances to the next step S5.

FIG. 7 shows one example of the result of measurement of the "rate" of the assembled movement. It can be seen that the "rate" of the "position on the 12 o'clock" changes from about +87 seconds/day to about -7 seconds/day, the "rate" of the "position on the 3 o'clock" changes from about +60 seconds/day to about +15 seconds/day, the "rate" of the "position on the 6 o'clock" changes from about +52 seconds/day to about +8 seconds/day and the "rate" of the "position on the 9 o'clock" changes from about +64 seconds/day to about

0 second/day as the balance swing angle changes from 100 degrees to 250 degrees.

Such positional difference meets with the standard when such result of measurement of the "rate" stays within the standard of the rate of the mechanical watch, so that it is judged that the adjustment of the rate is not necessary (Step S5 in FIG. 6). In this case, the rate adjusting work ends.

When the result of measurement of the "rate" exceeds the standard of the rate of the mechanical watch, the positional difference does not meet with the standard, so that it is judged that the adjustment of rate is necessary and the process advances to the next step S6.

(2.4) Calculate total adjustment and single weight:

With reference to FIG. 7, the total adjustment of the balance is calculated when it is judged that the rate must be adjusted (Step S6 in FIG. 6).

The total adjustment Z_c of the balance may be found based on data of preliminary experiment by using "inclination" and "intercept" of a straight line connecting an average value of rates of the four positions when the swing angle of the balance is 150 degrees and an average value of rates of the four positions when the swing angle of the balance is 250 degrees as shown in FIG. 7.

Here, the "intercept" is a coordinate value when a certain straight intersects with a standard axial line, e.g., a vertical axial line Y-axis. The "inclination" is tangent of inclination when a certain straight line intersects with a standard axial line, e.g., a horizontal axial line X-axis. For instance, a is "inclination" and b is "intercept" in a straight line $y = ax + b$.

That is, a preliminary test is carried out in advance for samples of the same type with the mechanical watch whose rate is to be adjusted to find the relationship among the inclination and intercept of the straight line connecting the average value of the rates in the four positions when the balance swing angle is 150 degrees and the average value of the rates in the four positions when the balance swing angle is 250 degrees and the total adjustment of the balance.

That is, it has been known by experiments that the precision of the watch (value of rate in the four positions when the balance swing angle varies) is good when the rewinding angle of the hair spring is 90 and 270 degrees in general in the mechanical watch.

Here, the "rewinding angle" is an angle in the circumferential direction to the position where the hair bar is located based on the position where the hair spring is fixed to the hair spring ball when the angle in the circumferential direction is defined by setting the original point at the

center of rotation of the balance.

Accordingly, the rewinding angle of the hair spring is estimated by using the inclination and intercept of the straight line found as described above. Next, the length of the hair spring (adjusted length) is calculated so that the rewinding angle of the hair spring becomes 90 or 270 degrees. Next, the difference (difference of length) between the length (adjusted length) of the hair spring and the actual length of the hair spring in the mechanical watch is calculated. Next, based on the result of calculation of the difference of the lengths, the rate of the mechanical watch may be adjusted by adjusting the length of the hair spring.

Accordingly, such method requires to find the relationship between the rewinding angle of the hair spring and the values of rates in the four positions in various balance swing angle in advance by carrying out the preliminary test on samples of the same type with the mechanical watch whose rate is to be adjusted.

According to the present invention, the preliminary test is carried out on the samples of the same type with the mechanical watch whose rate is to be adjusted in advance and the total adjustment of the balance is determined by using the result thereof.

According to the experiment using the inventive mechanical watch manufacturing method, the total adjustment

of the balance was about 0.3 mg for instance.

(2.5) Adjustment of rate:

Next, the steps for adjusting the rate by using the mechanical watch manufacturing method will be explained.

The mechanical watch manufactured by using the inventive mechanical watch manufacturing method is constructed so that a value of oscillation frequency of a hair spring controlling piezoelectric element 454 is greater than a value of an intrinsic oscillation frequency of a hair spring holding spring 452. Here, the timing of oscillation of the hair spring controlling piezoelectric element 454 is adjusted in conformity with the operation of the hair spring 140c of the balance 140.

That is, in FIG. 2, when the hair spring controlling piezoelectric element 454 is oscillated when the balance 140 rotates clockwise, the hair spring 140c moves clockwise from the position where it contacts with the hair spring controlling piezoelectric element 454 and the hair spring holding spring 452 and goes out from the hair spring controlling piezoelectric element 454 and the hair spring holding spring 452. In contrary to that, when the hair spring controlling piezoelectric element 454 is oscillated when the balance 140 rotates counterclockwise, the hair spring 140c moves counterclockwise from the position where it contacts

with the hair spring controlling piezoelectric element 454 and the hair spring holding spring 452 and enters towards the hair spring controlling piezoelectric element 454 and the hair spring holding spring 452.

The longer the oscillating effective length of the hair spring 140c, the more the rate of the mechanical watch delays and the shorter the oscillating effective length of the hair spring 140c, the more the mechanical watch advance in general in the mechanical watch. Accordingly, when the balance operation measuring apparatus 464 judges that the rate of the mechanical watch is advancing, the piezoelectric element driving apparatus 466 outputs a pulse for driving the piezoelectric element to the hair spring controlling piezoelectric element 454 based on a piezoelectric element driving control signal which is outputted by the balance operation measuring apparatus 464 in order to oscillate the hair spring controlling piezoelectric element 454 when the balance 140 is rotating clockwise.

When the balance operation measuring apparatus 464 judges that the rate of the mechanical watch is not advancing (delaying), the piezoelectric element driving apparatus 466 outputs a pulse for driving the piezoelectric element to the hair spring controlling piezoelectric element 454 based on the piezoelectric element driving control signal which is outputted by the balance operation measuring apparatus 464

in order to oscillate the hair spring controlling piezoelectric element 454 when the balance 140 is rotating counterclockwise.

The pulse for driving the piezoelectric element is outputted to a first pattern 420a of a piezoelectric element lead substrate 420 from the piezoelectric element driving apparatus 466 via a first driving terminal 430 and to a second pattern 420b of the piezoelectric element lead substrate 420 from the piezoelectric element driving apparatus 466 via a second driving terminal 432.

Thus, the oscillating effective length of the hair spring 140c may be prolonged/shortened by driving the piezoelectric element.

The length of the oscillating effective length of the hair spring 140c to be prolonged or to be shortened is found in advance based on the data of the preliminary test by using the "inclination" and "intercept" of the straight line connecting the average value of the rates in the four positions when the balance swing angle is 150 degrees and the average value of the rates in the four positions when the balance swing angle is 250 degrees as described above.

Then, the rewinding angle of the hair spring 140c is estimated by using the inclination and intercept of this straight line. Next, the length (adjusted length) of the hair spring 140c is calculated so that the rewinding angle of the

hair spring becomes 90 or 270 degrees. Next, the difference of the lengths between the length (adjusted length) of the hair spring 140c and the actual length of the hair spring 140c in the mechanical watch is calculated. Then, based on the result of this difference of lengths, the piezoelectric element is driven by the piezoelectric element driving apparatus 466 to adjust the length of the hair spring 140c. The data of the preliminary test and the calculation program of the difference of lengths are stored in the piezoelectric element driving apparatus 466 in advance.

In the inventive mechanical watch manufacturing method, the piezoelectric element lead substrate 420 is fastened to the main plate 102 by a substrate screw 428 after adjusting the rate of the mechanical watch as shown in FIG. 3. In this state, the first pattern 420a of the piezoelectric element lead substrate 420 shorts with the second pattern 420b in this state.

The hair spring 140c may be held reliably in the state after the adjustment by shorting the first pattern 420a of the piezoelectric element lead substrate 420 with the second pattern 420b.

FIGs. 1 and 3 show the movement of the mechanical watch after adjusting the rate thereof by using the inventive mechanical watch manufacturing method.

Here, FIGs. 8 and 9 show one example of the result of

measurement of the "rate" of the movement after adjusting the rate by using the inventive mechanical watch manufacturing method.

It can be seen that the "rate" on the "position on 12 o'clock" changes from about +7 seconds/day to about -9 seconds/day, the "rate" on the "position on 3 o'clock" changes from about -17 seconds/day to about +13 seconds/day, the "rate" on the "position on 6 o'clock" changes from about -25 seconds/day to about +4 seconds/day and the "rate" on the "position on 9 o'clock" changes from about -14 seconds/day to about -3 seconds/day as the balance swing angle changes from 100 degrees to 250 degrees by adjusting the rates by using the inventive mechanical watch manufacturing method.

It was found that the result of such measurement of "rate" stays within the standard of the rate of the mechanical watch.

It can be also seen that the value of "rate" after adjusting the rates by the inventive mechanical watch manufacturing method is a value indicating very good precision as a whole more than the value of "rate" before adjusting the rate as described before.

The use of such inventive mechanical watch manufacturing method allows the rate of the mechanical watch to be adjusted at high precision. Accordingly, the use of the inventive method allows a high precision mechanical watch

to be manufactured.

INDUSTRIAL APPLICABILITY

The inventive mechanical watch manufacturing method is suitable for adjusting the rate of the mechanical watch accurately with simple steps without decomposing the movement.

Accordingly, the inventive mechanical watch manufacturing method is suitable for manufacturing a high precision mechanical watch.



CLAIMS

1. A manufacturing method of a mechanical watch comprising a movement having a spring composing a power source of the mechanical watch, a front wheel train which rotates by rotational force which arises when the spring is unwound and an escape and governor for controlling the rotation of the front wheel train, wherein

the escape and governor comprising a balance which repeats right and left turns alternately, an escape wheel & pinion which rotates based on the rotation of the front wheel train and a pallet fork which controls the rotation of the escape wheel & pinion based on the operation of the balance; and

the balance comprising a hair spring, a balance stem and a balance wheel;

said mechanical watch manufacturing method comprising:

(a) a step of assembling the movement (400) of the mechanical watch;

(b) a step of measuring the rates of the assembled movement;

(c) a step of calculating the total adjustment of the balance (140) based on the result of measurement of the rates in the previous step (b);

(d) a step of calculating the oscillating length of



the hair spring (140c) to be adjusted based on the result of calculation of the total adjustment of the balance (140) in the previous step (c); and

(e) a step of adjusting the oscillating effective length of the hair spring (140c) by oscillating a hair spring controlling piezoelectric element (454) which is disposed in contact with the hair spring (140c) based on the result of calculation of the length of the hair spring (140c) in the previous step (d) to be adjusted.

2. The mechanical watch manufacturing method as described in Claim 1, characterized in that the measurement of the rate in the previous step (b) is carried out on four "vertical positions" of "position on 12 o'clock", "position on 3 o'clock", "position on 6 o'clock" and "position on 9 o'clock".

3. The rate adjusting method as described in Claim 1 or in claim 2, characterized in that the measurement of the rate in the previous step (b) is carried out by measuring the operation of the balance (140) while winding up the spring by using a balance operation measuring apparatus (464) and the balance operation measuring apparatus (464) measures the operation of the balance (140) by receiving light emitted from a light source (460) disposed so as to illuminate a balance arm (140f) by two light receiving sections (462a, 462b).

4. The rate adjusting method as described in Claim



3, characterized in that the balance operation measuring apparatus (464) stores the relationship between period of light entering the light receiving sections (462a, 462b) and a swing angle of the balance (140) in advance and calculates the swing angle of the balance (140) by using the period of light entering the light receiving sections (462a, 462b).

5. The rate adjusting method as described in any one of Claims 1 through 4, characterized in that the movement (400) of the mechanical watch comprises a piezoelectric element lead substrate (420), the piezoelectric element lead substrate (420) is provided with a first pattern (420a) and a second pattern (420b) and a pulse for driving a hair spring controlling piezoelectric element (454) is outputted from a piezoelectric element driving apparatus (466) to the first pattern (420a) and the second pattern (420b).

6. The rate adjusting method as described in Claim 5, characterized in that the piezoelectric element lead substrate (420) is fastened to the main plate (102) by using a substrate screw (428) after adjusting the rate of the mechanical watch by the step (e) to short the first pattern (420a) with the second pattern (420b) of the piezoelectric element lead substrate (420).