Claims

1. An automatic auxiliary calibration apparatus method, including standard steel balls (1), characterized in that, an outer surface of the calibration steel ball (1) is sleeved with an auxiliary apparatus (3), and the auxiliary apparatus (3) includes a collar (31), a rear surface of the collar (31) is equipped with a connecting column (33), a rear edge of the collar (31) is equipped with a chamfer (32), an outer surface of the connecting column (33) is sleeved with a calibration tube (2), and the calibration steel ball (1) includes a positioning steel ball (11), a sleeve groove (34) is formed on an front surface of the collar (31), the sleeve groove (34) is sleeved on the outer surface of the positioning steel ball (11), the outer surface of the positioning steel ball (11) is equipped with a connecting rod (12), and an outer end of the calibration tube (2) is equipped with a manipulator (4).

characterized by the following steps:

A. Install the calibration tube (2) on an outer surface of an end of the manipulator (4);

Set coordinate coefficient value of a center (Of) of a flange coordinate system is {Xf, Yf, Zf};

coordinate coefficient value of a center (Or) of a coordinate system of the manipulator 4 base is {Xr, Yr, Zr};

coordinate coefficient value of a center (Ot) of a coordinate system of the calibration tube 2 end is {Xt, Yt, Zt};

B. Fix the calibration steel ball (1) with radius of rb in the manipulator (4) coordinate system, the calibration steel ball (1) and the manipulator (4) need to keep strictly relative fixation, and the calibration tube (2) is installed on the outer surface of manipulator (4) end flange simultaneously;

C. Install the auxiliary apparatus (3) on an inner surface of the calibration tube (2), and buckle the auxiliary apparatus (3) on the outer surface of the calibration steel ball (1), at which time an axis O1 of the calibration tube (2) is set as a high line, a center of the calibration steel ball (1) is set as a vertex, generating a conical surface with an apex angle of 120°, an intersection of the conical surface and the calibration steel ball (1) is a movement route of the calibration tube (2);

D. Set the manipulator (4) to impedance mode, and apply a certain force along a direction of the calibration tube (2) axis O1 to the steel ball (1), the calibration tube (2) is buckled on a surface of the steel ball (1), at which time the calibration tube (2) axis O1 is L1, generatrix of the conical surface is L2;

A positional data of L1 in space is $T1=\begin{matrix} rL_1 & 0 & 0 & t_1 \\ 0 & rL_1 & 0 & t_2 \\ 0 & 0 & rL_1 & t_3 \\ 0 & 0 & 0 & 1 \end{matrix}$;

A positional data of L2 in space is $T2=\begin{matrix} rL_2 & 0 & 0 & t_1 \\ 0 & rL_2 & 0 & t_2 \\ 0 & 0 & rL_2 & t_3 \\ 0 & 0 & 0 & 1 \end{matrix}$;

Since two straight lines intersect at a center of the sphere, they are considered to be at the same position, but their directions are different, so thereby an amount of movement performed by the manipulator (4) is $T_3 = T_2^{-1} * T_1$;

E. On a movement trajectory of the manipulator (4), the positional data of the flange is collected at a certain angle every interval, and every 4 positional data is a group, and a Tool Center Point (TCP) data is obtained using the four-point method; if an error of the two groups of TCPs is less than an allowable value, calculation is stopped, otherwise automatic movement steps A-D are repeated.

2. The automatic apparatus calibration method according to claim 1, characterized in that, if not using auxiliary apparatus (3), a physical location of the calibration tube (2) TCP point is located coincident with the calibration tube (2) axis O1.

3. The automatic apparatus calibration method according to claim 1, characterized in that, if using the auxiliary apparatus (3), a physical location of the calibration tube (2) TCP point is located coincident with the calibration tube (2) axis O1.

4. The automatic apparatus calibration method according to claim 3, characterized in that, the auxiliary apparatus (3) is capable to be mounted on the front end of the calibration tube (2), a spherical center of a spherical surface on the auxiliary apparatus (3) is set as the tool center point.

5. The automatic apparatus calibration method according to claim 4, characterized in that, a cross-section of inner wall of the auxiliary apparatus (3) is circular.

6. The automatic apparatus calibration method according to any claim of 3 to 54~6, characterized in that, the auxiliary device (3) is configured to use concave spherical surface and the calibration steel ball (1) of same size for helping the tool to determine a point not on the tool surface as the tool center.

7. The automatic apparatus calibration method according to claim 2 or 3, characterized in that, a part where top surface A1 of the calibration tube (2) intersects with the inner wall is a standard circle, when the standard circle is buckled on the spherical surface, it is certain that the standard circle will through the center of the circle, and the straight line extending to the normal direction of

the surface where the circle is located will pass through the center of the calibrated steel ball (1), and the distance between the center of the ball and the center of the circle remains unchanged.

8. The automatic apparatus calibration method according to claim 7, characterized in that, the calibration tube (2) is a calibration tube (2) of straight cylinder class.

9. An automatic apparatus calibration method according to claim 8, characterized in that, the calibration tube (2) and the calibration steel ball (1) that are buckled on the calibration steel ball spherical surface by the auxiliary apparatus (3) are regarded as a whole, named as a tool, and the auxiliary apparatus (3) is installed at the front end of the sleeve and the center of the sphere on the auxiliary apparatus (3) is set as the tool center point.

10. The automatic apparatus calibration method according to claim 9, characterized in that, a physical position of the tool TCP point coincides with the axis O1 of the calibration tube (2), and there is a certain offset from the top surface A1 of the calibration tube (2), and an offset direction is a direction away from the tool.

11. The automatic apparatus calibration method according to claim 10, characterized in that, an offset distance of the physical position of the tool TCP point from the top surface A1 of the calibration tube (2) is $\sqrt{r_b^2 - r_s^2}$, located on a side away from the calibration tube (2), and rs is radius of the inner wall of the sleeve.

12. The automatic apparatus calibration method according to claim 10, characterized in that, the offset distance of the tool TCP point from the calibration tube (2) top surface A1 is determined by an auxiliary calibration tool size La, and La is a distance between the top surface A1 of the calibration tube (2) and the spherical center of the concave surface of the auxiliary apparatus (3) after the calibration tube (2) is installed with the auxiliary apparatus (3).

13. The automatic apparatus calibration method according to any claim of 1 to 12 , characterized in that, the manipulator (4) applies an appropriate amount of force in an axial direction of the calibration tube (2), and this direction is set as the Z-axis direction, concurrently, the manipulator (4) is set to the impedance mode, at which time rotational and translational damping in all directions is reduced, enabling it to move more freely; afterwards relatively movement is performed on the spherical surface according to a pre-set trajectory. At this point, the calibration tube (2) and the steel ball (1) that are buckled on the spherical surface of the calibration steel ball (1) by the auxiliary tool are regarded as a whole, that is, a new tool, and a relative rotation of the calibration tube (2) around the surface of the steel ball (1) is also regarded as a fixed-point movement of the new tool. The relative movement is the rotation around X and Y axes, and an amount of translation is set

to 0. At this time, due to the force along the calibration tube (2), the damping of the manipulator (4) is small, and with the help of the auxiliary apparatus (3), the calibration tube (2) is not easy to fall off, thereby the calibration tube (2) starts to do automatic movement around the spherical surface without a need of a positional data, and collect the positional data in real time, also use the four-point method to solve the TCP data.

14. The automatic apparatus calibration method according to claim 13, characterized in that, if a difference between the multiple TCP data is less than the allowable error, the movement is stopped, and output the calculation result.