Process design of BS15-1602001 clutch withdrawal fork

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Abstract. BS15-1602001 clutch withdrawal fork is one of the main components produced for certain enterprise. The special shape and the complicated conversion among design datum, positioning datum and measuring datum lead to difficulty in detecting the machining parts. This article focuses on the design and determination of the part process route from several aspects, such as the machining processability of the part material and structure, the selection of the rough positioning reference and the precision reference, the machining allowance and the determination of the dimensional tolerances, in which content involves knowledge of metal materials, machining, cutting tools, fixtures, equipment, heat treatment, etc.

1. Selection of process benchmark

According to the different functions of the datum, datum is divided into design datum and process datum, where the process datum can be divided into positioning datum, assembly datum and measuring datum. For the machining of components, the positioning datum should be considered firstly. The choice of positioning datum should be based on ensuring the accuracy of the spatial position. Choosing the main surface of the component for easily clamping could ensure a stable and reliable processing process. The selected positioning datum should take the larger surface as the mounting surface, the longer distance surface as the guide surface, the smallest size surface as the supporting surface to achieve the efficient, low-cost fixture design towards the convenient operation.

Based on the chart of the clutch withdrawal fork from BS15-1602001, the main processing part of the component is the two ball sockets and fork around the plane and two arc parts, while the main design datum is the middle ball socket Sφ13.2±0.1. Since it possesses the same spherical center with the tail sphericity nest Sφ9.2±0.2, at the same time center of two sides of the other end 60±0.1 has strict symmetry requirements, so listing Sφ13.2±0.1, Sφ9.2±0.2 as the centering reference and 60±0.1 as the finishing reference, respectively. Among them, Sφ13.2±0.1 plays the most important role in precision and reference. From the C-C sectional view, there are only two plane parts in the thickness direction, which are the upper plane of Sφ9.2±0.2 and the lower plane of the two arc surfaces of the fork R15. The above planes owe advantages of flat and smooth when they were selected as reference planes during the casting of the blank, thus beneficial for decreasing positioning error and reliable clamping. In order to machine the finishing reference ball socket Sφ13.2±0.1, making it meet the symmetry design requirements with the center surface of the outer side of the withdrawal fork 60±0.1, and the sphericity nest Sφ9.2±0.2 should follow the steps below. Firstly, the two planes of the positioning precision datum 60±0.1 should be processed in advance in accompany with selecting the outer circle of the tail φ18 and the two planes in the thickness direction as the positioning datum. Then, based on the φ18 outer circle and two planes as the positioning reference, adding both sides of 60±0.1 as the precision reference makes the position accuracy easier to ensure and the clamping more reliable and stable. Thirdly, Sφ13.2±0.1 ball socket is...
processed with two outer sides of 60 $-0.1_{-0.23}$ and Sφ9.2 $+0.2_{-0.1}$ ball socket as a precision reference, so that the dimensional accuracy and position accuracy can be easily guaranteed. At this time, Setting Sφ9.2 $+0.2_{-0.1}$ and Sφ13.2 $+0.1_{-0.0}$ two ball sockets as the machining precision reference to each other, then the dimensional accuracy and position accuracy of the parts can easily meet the design requirements.

2. Selection of processing method

To select processing method, we must first understand the economic precision and surface roughness that can be achieved by various processing methods, and select the appropriate processing method according to the material performance requirements, heat treatment requirements, dimensional accuracy, position accuracy and roughness requirements of parts provided in the part drawing. At the same time, one must take existing actual equipment conditions, the operating technical level of the operator, the unit’s estimated possible capital investment, the existing management level, the restriction requirements of the installation factory on the machining cycle of the components, the monthly installed capacity, and other factors into consideration. Different machining methods have different economic precision, so the most suitable machining method can be determined according to the specific situation.

The company's existing conditions: only ordinary equipment, when necessary can consider CNC machine tools.

The company's current production capacity: 2000 pieces per month, 5 days per week, single shift.

From the part chart, the ball socket Sφ13.2 $+0.1_{-0.0}$ and the width 60 $-0.1_{-0.23}$ possess small tolerances and the accuracy grade of IT10~IT11, which belong to hole and plane processing respectively, and the roughness requirement is Δ4, through common drilling and milling machine can meet the chart requirements. There is no special measuring tool for ball socket Sφ13.2 $+0.1_{-0.0}$, only can choose a three-coordinate machine to measure components to ensure the processing quality or through inspection and control of tools. To process the ball socket Sφ13.2 $+0.1_{-0.0}$, a special spherical countersink is required. While the manufacturing cost of a special spherical countersink is relatively high and the spherical countersink made of high-speed steel is one-time use and can not be sharpened. Moreover, the measurement of props is also difficult and the cost is high. Therefore, designing a special inner spherical surface measuring tool and figuring out how to control and detect tool wear are one of the key issues to improve production efficiency, reduce costs, and ensure component quality.

Secondly, the tolerance level of the tail ball socket Sφ9.2 $+0.2_{-0.1}$ is between IT12~IT13, which belongs to hole processing, requiring roughness of Δ3. could be easily met by common drilling machines. Much emphasis should also be paid to the detection of the ball socket and the sharpening and testing of spherical tools.

Finally, other processing parts φ4.2 $+0.1_{-0.0}$, 2-φ4±0.1, 2-R15±0.2 and their inner and outer chamfers can carry on positioning processing through two Ball sockets Sφ13.2 $+0.1_{-0.0}$, Sφ9.2 $+0.2_{-0.1}$ and two outer sides of 60 $-0.1_{-0.23}$. Among which φ4.2 $+0.1_{-0.0}$, 2-φ4±0.1 can be processed on a vertical drilling machine or an arm drilling machine, 2-R15±0.2 can be processed in a horizontal Machining on a type milling machine. The inner and outer chamfers of 2-R15 can be machined on the vertical milling machine with the rotation of the fixture after aligning the center of R15, which requires the two parts of R15 to be stable in size and consistent in processing. Only in this way can the two parts of R15 processed be uniformly consistent in inner and outer chamfering and meet the requirements of the design chart.

3. Division of components processing sequence

The processing sequence of components refers to the sequence of the processing procedures of the parts, which maintains close relationship with the processing quality, production efficiency and machining economy and is one of the keys to drawing up the machining process route of components. The blank of BS15-1602001 clutch withdrawal fork parts adopts sand casting method. Except for two reference planes requiring high casting precision, the casting precision of other external surfaces is relatively low, so it is necessary to process the four planes of two ball sockets and withdrawal fork firstly. After that, the other holes, arc surfaces, and chamfers of the parts are processed as precision datums, so that the dimensional accuracy and position accuracy of the parts can meet the design requirements.
According to the principle of first roughing then fine and first main then second, the processing order of parts is formulated as follows:

Plane datum—centering datum—milling arc—drilling—chamfering—high-frequency quenching.

### 4. Determination of part process route

Through the above analysis, in accordance with the principle of process concentration and facile production management, the process route is formulated as shown in Table 1.

| Process sequence | Type of work | Processing content | Positioning datum | Description |
|------------------|--------------|--------------------|-------------------|-------------|
| 1                | Spray paint  | Painting the entire surface of the component black | No | Outsourced processing |
| 2                | Miller       | Machining the four planes of the two forks | Outer circle of 18 and two reference planes | Establishing a precise datum |
| 3                | Fitter       | Processing ball socket $S\varphi 9.2 \, ^{+0.2}_{-0^2}$ | Both ends of $60 \, ^{+0.1}_{-0.23}$, outer circle of 18 and two reference planes | Establishing a precise datum |
| 4                | Fitter       | Machining ball socket $S\varphi 13.2 \, ^{+0.1}_{-0.2}$ and hole $\varphi 4.2 \, ^{+0.1}_{-0.1}$ | Two outer sides of $60 \, ^{+0.1}_{-0.23}$, two reference planes and ball socket $\varphi 9.2 \, ^{+0.2}_{-0^2}$ | Establishing a precise datum |
| 5                | Miller       | Two R15 arcs | Two outer sides of $60 \, ^{+0.1}_{-0.23}$ and two ball sockets | |
| 6                | Fitter       | hole $2\varphi 4 \pm 0.1$ | Ball socket $\varphi 9.2 \, ^{+0.2}_{-0^2}$ and 2-R15 arc surface | |
| 7                | Miller       | Chamfer the inside and outside of two R15 arcs | Ball socket $S\varphi 13.2 \, ^{+0.1}_{-0.2}$ and $60 \, ^{+0.1}_{-0.23}$ on both outer sides | |
| 8                | Fitter       | Deburring | No | |
| 9                | High-frequency quenching | High-frequency quenching of two R15 arc surfaces | No | |
| 10               | Washing      | Washing | No | |
| 11               | Examining    |                   |                  | |

### 5. Process design of main processing procedures of components

#### 5.1. Machining of four planes of withdrawal fork $60 \, ^{+0.2}_{-0.23}$

The two outer sides of the fork $60 \, ^{+0.1}_{-0.23}$ are the two places with the highest geometric tolerance and economic grade requirements among the only four plane parts that need to be processed in the whole part, and they are one of the main datums for the entire machining process. Except for the outer circle of the tail $\varphi 18$ and the two planes in the thickness direction of the component blank, which are relatively flat and smooth, the other surface parts are relatively rough. The two planes in the thickness direction and the tail $\varphi 18$ outer circle have features of higher precision requirements, the most stable quality, and the smallest casting offset from other surfaces in the blank manufacturing process, so they are selected as the positioning reference during the machining. So that the positioning error of the parts is controlled
within the minimum range, and then the proper tightening point is selected, and the whole installation process of the parts is firm and reliable.

![Diagram](image-url)

**Figure 1.** Machining of four planes of withdrawal fork $60^\circ_{0.2}$.

During machining, placing the parts on three positioning reference pins, fixing the $\phi 18$ excircle with V-shaped block, inserting the ball socket $S\phi 13.2_{0.1}$ with bolt, and pressing the spherical part of the tail ball socket $S\phi 9.2_{0.2}$ with pressing plate, so that the whole part is fixed on the fixture. After trial cutting adjustment, four planes can be machined on the vertical milling machine at one time with four disc milling cutters. The spindle speed of the machine tool is selected as 60 rpm, and the feeding mode is manual.

The technological advantages of this procedure are stable positioning and small positioning errors, ensuring a uniform margin for subsequent procedures. The disadvantages are that the clamping efficiency of parts is relatively low, and because of the casting deviation error of parts blank, after four planes are processed, the removal allowance is uneven, the wall thickness difference is large, and the visual appearance effect is not good. The processing of the four planes of the parts is shown in figure 1.

5.2. **Machining of the ball socket $S\phi 9.2_{0.2}$ at the part tail**

As shown in the part drawing of BS15-1602001 clutch release fork, both the spherical center of $S\phi 9.2_{0.2}$ and the central surfaces of the two outer sides of $60^\circ_{0.2}$ of the releasing fork together construct the central surface of the whole part arm. Thus, the two outer sides of $60^\circ_{0.2}$ are selected as the positioning precision reference, and the ball socket $\phi 13.2_{0.1}$ is selected as the centering rough reference. In addition,
Φ 18 excircle and the lower two planes in the thickness direction of the part are used as coarse positioning references to process the ball socket Sφ9.2 +0.2 , which could reduce the positioning error of the part and laying the foundation for ensuring the symmetry requirement of the ball center of S φ13.2 +0.1 with the center of the arm.

As this ball socket has a 60-degree conical surface in addition to the spherical surface of Sφ9.2 +0.2 , if two knives are applied for machining, the production rhythm of this process will slow down, and the problem of eccentricity of knives will also occur, which makes it impossible to achieve ideal tangency between the spherical surface of Sφ9.2 +0.2 and the conical surface of 60 degrees, resulting in quality defects such as steps and scratches, which cannot meet the requirements of designs. Therefore, by using a forming knife, the two cases could be avoided, but there also exists some problems such as the detection and grinding of the knife mentioned above.

During processing, the parts are placed on the fork two positioning pins and the other supporting pin of the tail, outer circle φ18 was fixed with V-shaped block, the ball socket Sφ13.2 +0.1 is inserted with a plug, and then two outside face of 60 +0.2 should be clamped properly with suitable force in order to reduce the workpiece deformation, at the same time the tail ball socket Sφ9.2 +0.2 is pressed firmly with the pressure plate. In this way, the whole part is fixed on the drill die. Guided by the drill sleeve with a forming countersunk cutter, and the upper plane of φ18 is taken as the processing and measuring datum, the depth of 8±0.2 is easily to achieve. However, due to the casting error of the parts, the processed surface part has uneven wall thickness with the outer circle of φ18, which needs to be controlled when casting the part blank. The spindle speed of the machine tool is selected to be 900rpm, and the feeding mode is manual.

The advantage of this process is that the positioning of the parts is stable and reliable, but the disadvantage is that the installation of the parts is cumbersome and the efficiency is relatively low.
The processing of the tail φ9.2 +0.2 0 ball socket is shown in figure 2.

5.3. Machining of ball socket Sφ13.2 +0.1 0
Sφ13.2 +0.1 0 is the one with the highest requirements for dimensional tolerance and shape tolerance in the entire machining dimension of components. It acts as a fulcrum to realize clutch separation through torque transmission, and its accuracy will affect the stability and reliability of clutch action. Therefore, it is one of the key processes in the whole process route of components.

When machining the ball socket Sφ13.2 +0.1 0, two planes in the thickness direction and the outer circle of tail φ18 are taken as the rough positioning datum, the center of tail Sφ9.2 +0.2 0 is taken as the centering fine reference, and the two outer sides of the machined separation fork 60 -0.1 -0.23 are taken as the positioning fine reference in the width direction, so that the location precision of the ball socket Sφ13.2 +0.1 0 namely its eccentric requirements between center of the ball and withdrawal fork arm can meet the design requirement. However, the dimensional accuracy of the ball socket Sφ13.2 +0.1 0 should be realized by the tool. Similarly, the inspection of the ball socket after machining, the inspection of the tool shape and the grinding after wear are the key points in this process.

The installation process is to place the components on the three positioning pins in the thickness direction, the 60 +0.1 -0.23 outer sides of the fork are fixed, and the pressing point is selected on the spherical surface at the tail where the socket of Sφ9.2 +0.2 0 is located, and on the fork part close to the machining location. In this way, the deformation of the parts is the smallest, the clamping of the parts is firm, and the dimensional stability is also good. Because of the costly and difficulty in controlling the production site of parts for three-coordinate measurement to measure the inner spherical surface Sφ13.2 +0.1 0, the processing of the inner spherical surface of Sφ13.2 +0.1 0 adopts a spherical countersink. With the permission of the design, we have adopted the method of measuring the tool to manufacture the profile model of the measuring tool to detect the wear of the tool at any time. This detection method is difficult.
to accurately control the size of the parts, and there exists hidden quality problems, so by using the special measuring tools to directly inspect parts is an effective way to eliminate the hidden trouble of quality. This process is processed on the arm drilling machine, the spindle speed of the machine tool is selected as 900 rpm, and the feed method is manual. The processing of ball socket φ13.2 $^{+0.1}_{-0.0}$ is shown in figure 3.

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