Research on Manufacturing Process for Cross-Braced End of Bogie

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Abstract. To overcome the manufacturing defects and improve the manufacturing quality of the end of the cross-braced of Bogie, through the analysis of a rough and a formed structure of the end of the cross-braced, the stress situation in the key tapping process of the inner hole is calculated, the tapping process and the corresponding parameters are determined, and the corresponding control strategies are put forward for other key processes in the manufacturing. Through a large number of production practice, the manufacturing process can significantly improve processing quality, improve production efficiency and reduce production costs of the end of the cross-braced of Bogie.

1. Introduction
With the rapid development of rail transit equipment, the high-speed and heavy-duty railway freight cars are gradually promoted, which put forward higher requirements for the performance, quality, stability and safety of bogies [1]. Each part of the Bogie is subjected to complex forces during the train is running. Due to the existence of these complex forces, the machining precision and quality of each part must be fully guaranteed [2].

Cross bracing technology bogies are a type of bogies that are currently widely used[2-3], but there are still many problems in actual production, especially in the processing technology of the end of the cross-braced of Bogie[4], which mainly exist in: One is the poor processing quality of the end of the cross bar, the high rejection rate, the depth of end thread processing is out of tolerance, the control of thread depth processing is unstable, the end thread processing is unqualified by the inspection, and the thread processing roughness is high; the second is that the cost of cross-braced end processing tools is high, and the waste rate of SPIRALOCK taps is too high; the third is that the tap and the processing equipment are not completely matched, the processing parameters are set unreasonably, and the operator is not fully familiar with the use of the new tap grasp.

The research and implementation of this article are of great significance to the manufacturing precision of cross-braced bogies, the manufacturing level of key components, the reduction of production costs and the improvement of production efficiency.
2. Analysis of structure of cross-braced and end of cross-braced

2.1. Brief description of the structure of the cross-braced

As the key cross support component of the K2/K6 bogie, cross-braced is composed by upper cross brace, lower cross brace, upper gusset, lower gusset, U-shaped elastic pad, X-shaped elastic pad, washer, nut and bolt. An X-shaped elastic cushion is sandwiched between the upper cross brace and the middle socket of the lower cross brace. A U-shaped elastic cushion and a cross bar upper gusset are installed on the outside of the middle socket of the upper cross brace. U-shaped elastic cushions are installed on the outside of the middle socket of the lower cross brace. The pad, the lower gusset, the upper gusset and the lower gusset are fastened by two sets of M12 bolts, M12 nuts, and M12 washers. The entire cross support part is fastened to the lower end of the side frame through the end of the cross brace.

2.2. The structure of the cross brace

The cross brace is composed by a cross bar shaft and a cross bar end. The total length of the cross brace is required to be 2201±1.5mm. The plane of cross bar end must be perpendicular to the canter line of the entire cross bar shaft. The straightness of the entire cross brace must be controlled within 3mm.

The cross bar end is a key component to ensure the technical performance of the cross brace. The material of the rough part processed by the cross bar end is Q345C, which is formed by a 0.5T electro-hydraulic hammer with a special forging die, and is quenched and tempered for heat treatment to make its yield strength $\sigma_s \geq 345\text{MPa}$, tensile strength $\sigma_b \geq 550\text{MPa}$, impact energy at -20°C is not less than 18J.

The total length of the rough part is 155.4mm, the diameter of the large end is 118.0mm, and the flange thickness is 11.3mm. The large end of the end and the end body adopt a radius of 28.6mm for rounded transition. The end body is a cone with a length of 115mm. The radius of the body, the cone and the fillet is 51mm, and the radius of the small end is 46.3mm.

3. The manufacturing process of cross bar end

3.1. Analysis structural of the cross bar end

Through the comparison of the tip manufacturing process drawing and the rough structure drawing, the machining process of the tip is mainly concentrated on the large end face and outer circle of the tip, the countersunk threaded hole and the cross bar end where the tip body is connected with the cross bar shaft.

From figure 1, the machining datum of the entire part is at the end of the end body. In terms of form and position tolerances, there are perpendicularity requirements for the large end surface of the end, the outer circle of the end large end has coaxiality requirements, and the threaded holes have coaxiality requirements. The countersunk threaded holes are SPIRALOCK anti-loosening threads and blind hole.

![Figure 1. The structure of cross bar end.](image-url)
3.2. The manufacturing process of the cross bar end

According to the processing requirements and processing accuracy of the entire part, and at the same time to save processing costs, it can be processed by ordinary horizontal lathes. According to the machining positioning datum and shape tolerance requirements, the machining process is determined as follows: the large end face and outer circle of the rough turning end with sufficient machining allowance; the tail end and outer circle of the fine turning end body; the large end face of the fine turning And the outer circle; drilling the threaded bottom hole; the countersunk hole of the turning tool thread; the SPIRALOCK tap tapping; the size inspection.

The specific processing procedures are as follows:

(1) Processing the big end and outer circle of the end. According to the taper of the end body, a special fixed taper sleeve is designed and manufactured, and the upper end of the three-jaw chuck of the machine tool is ground to match the taper of the upper end with the taper of the end body at $\phi 48$mm; The claw chuck and the special fixed taper sleeve designed for the end clamps the part where the diameter of the end is $\phi 48$mm; The amount of the back tool is $\leq 3$mm, the feed rate $f=0.4$mm/r, and the spindle speed $n=300$r/min. The large end face of the end is roughed with a 1mm machining allowance; the same processing parameters are used to rough the outer circle of the end large end with a 1mm machining allowance.

(2) Processing the terminal body. Use a three-jaw chuck to clamp the outer circle of the large end of the end; cut it according to the length of 147mm; finish turning on the end of the end body (the part inserted into the cross bar) to produce a $6\times 45^\circ$ chamfer; The head, body and tail are processed by fine turning to ensure that the diameter is $\phi 35.8\pm 0.1$mm, and the size to the large end face of the end is $97\pm 1$mm; the bevel angle is $120^\circ$. The processing parameters of each part are the back-cutting amount $\leq 3$mm, the feed amount $f=0.3$mm/r, and the spindle speed $n=200$r/min.

(3) Finish machining of the large end face and outer circle of the end head. Clamp the end of the head and body, and finish turning the large end face with the amount of back tool $\leq 3$mm, feed rate $f=0.3$mm/r, and spindle speed $n=400$r/min to ensure a thickness of 6.4mm and end face perpendicularity $\phi 0.38$mm And the roughness is $6.3 \mu m$; Carry out fine turning on the outer circle of the large end with $\leq 3$mm, $f=0.3$mm/r, $n=200$r/min, and determine the diameter $\phi 103_{-1.5}^{+0}$ mm.

(4) Drill the threaded bottom hole. Keep the end clamping in the previous step, use a $\phi 21.5$mm drill bit to machine the end threaded bottom hole with the spindle speed $n=170$r/min , ensure the hole depth is $103_{-1.5}^{+0}$ mm and the diameter is $\phi 21.5$mm.

(5) Expanded threaded countersunk hole. Keep the end of the previous process clamped, and change the turning tool to ream the threaded bottom hole to ensure that the hole depth is 25.4mm, the hole diameter is $\phi 27$mm, and the roughness is 6.3 $\mu m$.

(6) SPIRALOCK tap tapping. Keep the end clamping of the previous step, use the M24×3 SPIRALOCK special tap to tap the M24X3 internal thread at the spindle speed $n=18$r/min to ensure the thread depth 70_{-2.5}^{+0}$ mm.

(7) Dimensional inspection. Clean up the iron filings and burrs on the end head, and size the end head according to the requirements of the drawing. To check the threaded hole, you must use the SPIRALOCK special pass and stop rules.

4. The control of the key manufacturing process of cross bar end

4.1. Analysis of the key processing position of the cross bar end

The processing of the entire cross bar end is focused on the processing of internal threads. The internal thread of the end is a SPIRALOCK anti-loosening thread, which has a good anti-loosening effect when matched with the bolt.
4.2. Analysis of internal thread of the cross bar end subject to force in tapping

The machining quality of the internal thread of the cross bar end mainly depends on the action of various forces during tapping cutting. In this paper, the force analysis of the whole tapping cutter tooth of the spinneret is carried out.

As shown in Figure 2, when the cross bar end tapping is processed, the cutting resistance of the $i$ tapping cutter tooth of the tap is assumed to be $F_{ci}$, the positive pressure on the three contact surfaces of the cutter tooth and the part are respectively $N_{i1}$, $N_{i2}$, $N_{i3}$, and the corresponding friction forces are respectively $f_{i1}$, $f_{i2}$, $f_{i3}$.

The above-mentioned forces can be synthesized into a component force $F_i$ which parallels to the direction of the cutting speed in the cutting plane and a radial component force $r_iF$ which perpendiculars to the direction of $V_c$. If ignoring the slight difference in the cutting width of adjacent cutting teeth, the resultant force of the radial component force generated $rF$ by each tooth of the tap is 0, that is:

$$ F_i = \sum F_{ri} = 0 $$

The component force of the $i$ tooth of the tap in the cutting plane is the resultant force of the cutting resistance and the frictional force on the flank face of the tooth, which is $F_i = F_{ci} + f_i$. $f_i$ is caused by the elastic rebound of the machined surface. $f_i$ can be expressed as formula (2), $\alpha_0$ is back angle of tap:

$$ f_i = f_{i1} + f_{i2} + f_{i3} \cos \alpha_0 $$

Because of the spiral angle $\lambda$ of the tap teeth, $F_i$ can be decomposed into tangential component force $F_{ti}$ which parallels to the $x-o-y$ plane and the axial component force $F_{ai}$ which perpendiculars to the $x-o-y$ plane, they can be expressed as formula (3).

$$ \begin{align*}
F_{ti} &= F_i \cos \lambda = F_{ci} \cos \lambda + f_i \cos \lambda \\
F_{ai} &= F_i \sin \lambda = F_{ci} \sin \lambda + f_i \sin \lambda
\end{align*} $$
During the tapping process, the tangential component force $F_{ti}$ of each tooth of the tap determines the tapping torque $M$. From the first formula of formula (3), $F_{ti}$ is composed by the force of $F_{ci}$ and along the tangential component $f_{i}$. Then the tapping torque $M$ is composed by cutting torque $M_{c}$ and friction torque $M_{f}$, we can get the formula (4):

$$M = M_{c} + M_{f}$$

The axial component force $F_{ai}$ of each cutter tooth determines magnitude of the axial force $F_{a}$ in the tapping process. $M$ and $F_{a}$ can be expressed as formula (5):

$$\begin{align*}
M &= \sum_{i=1}^{m} F_{ci} r_{i} \cos \lambda + \sum_{i=1}^{n} f_{i} r_{i} \cos \lambda \\
F_{a} &= \sum_{i=1}^{m} F_{ci} \sin \lambda + \sum_{i=1}^{n} f_{i} \sin \lambda
\end{align*}$$

In the formula (5): $m$ is the number of cutting teeth; $r_{i}$ is the radius of gyration of the cutting edge of the $i$ tooth (m); $n$ is the number of teeth of the tap working simultaneously (the sum of cutting teeth and calibration teeth).

At the end of tapping, during the reverse drilling process of the tap, the $i$ tooth of the tap is subjected to the positive pressure $N'_{1i}$, $N'_{2i}$, $N'_{3i}$, and the friction force $f'_{1i}$, $f'_{2i}$, $f'_{3i}$, generated by the positive pressure between the flank face of the tooth tip and the two sides and the surface of the machined thread, as shown in Figure 3.

The above-mentioned forces are combined into a component force $F_{i}$ which parallels to the cutting speed direction $v_{c}$ and a radial component force $F_{r}$ perpendicular to the direction of $v_{c}$ in the cutting plane. The total force $F_{r}$ of the radial component forces generated by each tooth is zero.

$F_{i}$ is only composed by the flank friction of the tooth, the torque $M$ is only composed by the friction torque $M_{f}$. The torque $M$ and axial force $F_{a}$ during the reverse drilling of the tap can be expressed as formula (6):

$$\begin{align*}
M &= \sum_{i=1}^{n} f_{i} r_{i} \cos \lambda \\
F_{a} &= \sum_{i=1}^{n} f_{i} r_{i} \sin \lambda
\end{align*}$$

From equations (5) and (6), it can be seen that when tapping the end, the tap torque is the main factor affecting the processing quality. If the cutting torque can be controlled in an appropriate range, the tapping torque can be effectively controlled, so that the end can be processed with good quality.

4.3. Control strategy for key processing parts of the cross bar end

In order to improve the qualification rate of end processing, a lot of practices have been carried out and various measures have been taken to appropriately reduce the tapping torque:

(1) In terms of overcoming the defects of stop-regulation: Since the internal thread of the end parts is a blind hole, deepen the bottom hole of the thread as much as possible when drilling. After test verification, the depth of deepening is above 1.2mm, which can effectively overcome the defect of non-stop regulation, but the depth of the bottom hole has strict requirements, and there is not much room for deepening; ensure that the center of the bottom hole is collinear with the center of the tap, especially when drilling the bottom hole, as the drill processing time increases, the more serious the
wear, the drill should be timely Perform grinding; when fixing the tap, make the tap have a certain amount of floating; strictly use the pitch for tapping; ensure that the cutting fluid used has good adhesion resistance; reduce the tapping spindle speed according to the actual situation.

(2) In terms of overcoming the flaws of the general rules and regulations: thoroughly remove the chips at the end; adopt a lower reverse speed to retract the tool; when the chips are found to produce whisker-like chips, the tap knife edge should be trimmed in time to keep the knife edge well The sharpness.

(3) In terms of overcoming the surface quality defects of the internal thread of the end head: use cutting oil with stronger anti-adhesion properties and increase the oil injection speed; appropriately reduce the cutting speed.

(4) In terms of overcoming the defect of internal thread tooth tip wear: when drilling the threaded bottom hole, it is necessary to avoid its work hardening; when grinding the tap, prevent the blade rake angle from being too large; use cutting oil with stronger anti-adhesive properties And increase the oil injection speed; appropriately reduce the cutting speed.

(5) In terms of overcoming tap breakage: clean the chips in time to avoid clogging of the chips; reduce the cutting speed in time; ensure that the tap and the threaded bottom hole are at the same centerline; the tapping tool holder should be torque-adjustable, so as to be based on actual processing , Control the tapping torque; timely grind the tap knife edge and thoroughly remove the built-up tumor, sintered or adhesive material on the tap; when grinding the tap knife edge, pay attention to the thickness of the blade not to be too thin.

(6) In terms of preventing damage to the blade, when the tapping depth of the internal thread at the end is sufficient, avoid the immediate reversal to retract the tool; always ensure that the tap and the bottom hole of the thread are at the same center line to prevent the tapping from cutting in the axial direction. The impact force is too large; appropriately reduce the cutting speed; remove the chips in time to prevent the discharge port from being blocked; the cutting fluid is supplied sufficiently to avoid chip sticking. In overcoming the bonding defects of tapping, cutting fluid containing extreme pressure agent can be selected; cutting speed can be controlled.

5. Conclusion
In this paper, the above-mentioned processing procedures for the end manufacturing and proposes corresponding processing control strategies for the processing of the cross bar end. It provides guidance for the rapid and correctly selection of processing technology. Opinions have effectively ensured the manufacturing quality of the terminal and achieved remarkable results in overcoming the manufacturing defects of the terminal in actual production:

The scrap rate of processing has been reduced to less than 2%, and the manufacturing quality has been significantly improved. Tool costs are greatly reduced, which greatly saves manufacturing costs, the production efficiency has been greatly improved.

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