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Design of Hydraulic Arm For Disaster Relief Robot

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ABSTRACT: This paper mainly introduces the calculation and design of the hydraulic arm of the disaster relief robot, and discusses the structural design of the main components of the hydraulic arm of the disaster relief robot, and the strength of the main force parts of the hydraulic arm Check. Completed the design of the hydraulic arm of the disaster relief robot.

Index Terms: the disaster relief robot, strength, hydraulic arm.

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I. INTRODUCTION

At present, the earthquake disaster events occur frequently in the world, so with independent intelligence or semi-autonomous intelligence disaster relief robot for dangerous and complex conditions of search and rescue survivors is necessary to promote the development of relief robot hydraulic arm, The design of the hydraulic arm hand is getting mechanized and more automated [1]. Disaster relief robot hydraulic arm is still unable to achieve the staff as flexible, but it has a better advantage than the staff, such as the ability to continue to repeat the work and labor, tireless, not afraid of danger, grab the weight of heavy power than the characteristics of large. As a result, the development of hydraulic arm of relief robots has received increasing attention and has been widely applied [2]. In order to better carry out disaster relief, the application of the latest robot rescue technology at home and abroad to China's specific reality, the development of more practical value of the disaster relief robot work device, has become the urgent task of today's disaster relief technology development.

China's robot hydraulic arm research is relatively late, has experienced the seventies of the germination, the development of the 1980s and the 90's for the application. Although our country started in this area late, but it is popular concerned[3]. The National "second five" science and technology support program key project "lobster" rescue robot is the world's largest rescue robot [4]. Its work device is two arms, each arm has seven degrees of freedom, the staff can control the arm free rise and fall, but also to imitate the human arms for effective coordination and cooperation, the robot can wheel, track two Driving mode. Several American university research centers, national research institutions and companies have also carried out research on disaster relief robots [5]. The University of South Florida's Disaster Relief Robot Research Center has developed a rescue robot, Bujold, which has medical sensors mounted on the bottom of the robot and is driven by a deformable track with high motion and detection capability, and the robot can also be obtained at the disaster site The survivor's physiological information and the surrounding environment and send it to the outside world [6].

Based on the excavator chassis, the design of relief robot hydraulic arm can lift reinforced concrete blocks, and cut steel. The robot uses a tracked chassis, it can be more easily in the road complex rescue sites to implement the rescue work, expanding the scope of work, adaptability.
Technical parameters:

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Maximum operating range: 6 m ;
Crawl ability: 1.5 t ;
degrees of freedom: 4.

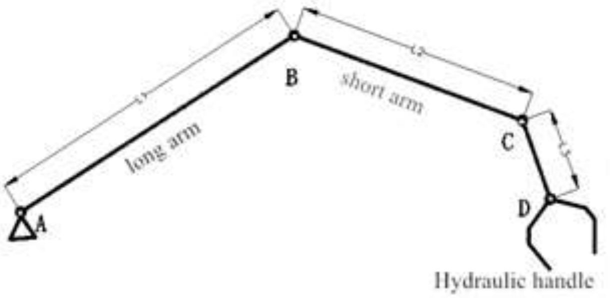

Figure 1 Hydraulic arm structure

II. DESIGN OF HYDRAULIC ARM STRUCTURE

The hydraulic arm adopts the tracked chassis structure to realize the rotary motion. In addition, the wrist at the short arm is set up to maintain the freedom of the end effector. As shown in Figure 1. The length of the long arm $L1$, the length of the short arm $L2$, the length of the wrist $L3$, the length of the arm of robot should meet: $L1+L2+L3 \geq 6m$ .The configuration diagram of the hydraulic arm can be composed of four points A, B, C, D and three rods, A, B, C and D are the center of the boom and wrist hinge holes.

In order to prevent the interference between the arm and the handle, while ensuring the actual work needs to make the wrist can be the largest range of activities, reference excavator bucket rotation angle, the design of the wrist rotation range of 120 degrees, Figure 2 marked the arm in the The range of the stroke when the fingertip is at the limit position.

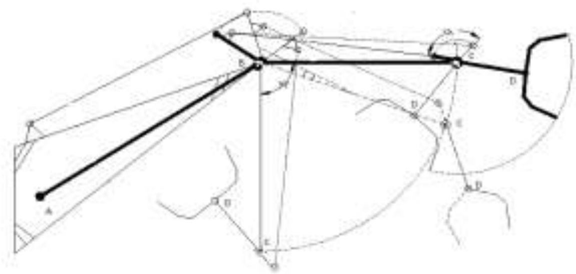

Figure 2 The trajectory of the hydraulic arm

III. DESIGN OF COMPONENT STRUCTURE OF HYDRAULIC ARM

3.1 Hydraulic handle design

3.1.1 The starting point of the design goals

The maximum height of the handle from the ground is 2000 mm; the depth of the ground below the maximum height of 500 mm; grip the maximum load of 1.5 t ; the maximum capacity of 0.45 m^2 . Hydraulic handle mechanism in figure 3 as follows:

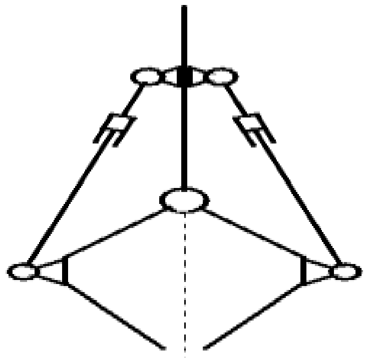

Figure 3 Hydraulic handle mechanism

According to the degree of freedom calculation formula:

$$F = 3n - 2P_L - P_H$$

The degree of freedom of the hydraulic handle can be calculated. Where the entire grasp of the handle by the two parts of the composition, so you can calculate half of the degree of freedom.

Where: n represents the active component is 3;

P_L on behalf of the low vice 4

P_H on behalf of the high pair of 0.

The degree of freedom is calculated as $F = 1$

3.1.2 The hydraulic handle specific parameters to determine

(1) Calculation of the hydraulic handle's maximum weight:

According to the maximum effective area of the hydraulic handle chamber: $s = 0.45m^2$, The width of the handle is 0.6 m ;it can be determined the weight of the gripper when the handle is closed or open. Assuming that the handle is completely filled with small stones, the stone and granite, its density is $2.6 - 3.3g/cm^3$, we can see the maximum weight : $M = 891Kg$ which is far less than 1.5, so the design is reasonable As shown in Figure 4.

(2) Calculation of the maximum grabbed stone length:

The width of the handle is set to 0.6m, and the longitudinal nonuniformity coefficient of the stone is: $k = 1.5\,t$, and the maximum length of the grabbed stone is $L_{\min} = 1.8$.

(3) the maximum width of the grabbed stone:

As shown in Figure 4, set $de = 255mm$, $ek = 100mm$, so that: $L2 = 2\times(de\times\cos 30^\circ + ke\times\sin 30^\circ) = 491.75mm$

(4) The grasp's gap after grasping:

the gap as shown in Figure 4, set $kg = 200mm$ .So that: $L2 = 2\times(de\times\sin 30^\circ + ke\times\cos 30^\circ) = 22.7mm$

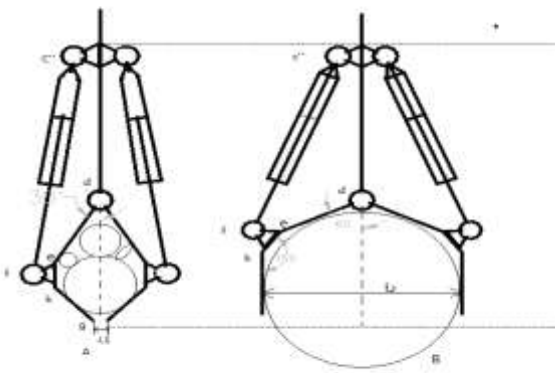

Figure 4 gripping object graph

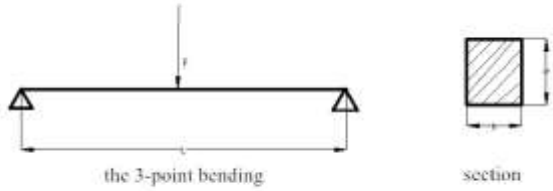

Figure 5 Check the bending strength of the handle

(5) Determination of the thickness of the hydraulic handle

The 45 steel yield limit $\sigma_s = 650Mpa$, bear the maximum stress $\sigma_b = 490 - 650Mpa$. The bending strength of the hydraulic handle is checked by the way that the 3-point bending method is loaded, and $L = 0.6m$ is the maximum width of the handle. The b , h section is the handle of each column (the width of the handle can be divided into 12 columns) of the sample cross-section $b = 0.05m$, take F for the maximum force of $15000N$, as shown in Figure 5.

The calculation formula of the bending moment of the simply supported $M = FL/4 = 9000Nm$, the calculation Formula of Resistance Moment of Rectangular Section : $W = \frac{bh^2}{6}$,The Strength calculation formula: $\sigma = \frac{M}{W} = \frac{FL}{4} \times \frac{6}{bh^2} = \frac{3FL}{2bh^2} \le [\sigma]$, so that: $h \ge 26.31mm$, So the thickness of the primary steel plate is $30mm$.

(6)The quality of the hydraulic handle to determine

Set $be = 225mm, ef = 100mm, fg = 200mm$,the thickness $h = 30mm$ .The total width of $600mm$, the size of the handle can be calculated $L = 9450000mm^3$,The 45 steel density is $7.85g/cm^3$, The quality of the handle is about $74.18kg$. And the grip mechanism consists of two parts, so the entire handle device is $148.37kg$.

3.1.3 The choice of the handle cylinder

According to the maximum external load of the hydraulic handle, we can design and calculate the structure of the handle hydraulic cylinder: $L1$=1000mm is the length of the vertical projection of the handle, $L2$=1000mm is the length of the hinge point of the handle cylinder to the articulation point of the hydraulic cylinder wrist, which is suffered a vertical force $F = 15000N$.

$$F_1 = F_a \cdot \sin 20^\circ, F_2 = F \cdot \tan 45^\circ, F_1 = F_2$$

$F_a = 43857N$, the hydraulic cylinder diameter is selected as $50mm$. The working pressure of the hydraulic cylinder $P = \frac{F}{s} = 22.35Mpa$.

Calculate cylinder bore diameter:

$$D = \sqrt{\left(\frac{4F_a}{pi \cdot (P - P_0)\eta_m} - \frac{d^2 P_0}{P - P_0} \right)}$$

$P_0 = 1Mpa$; η is mechanical efficiency, η = 0.95, through the calculation and checklist GB / T2348-1993, get $D = 50mm$.

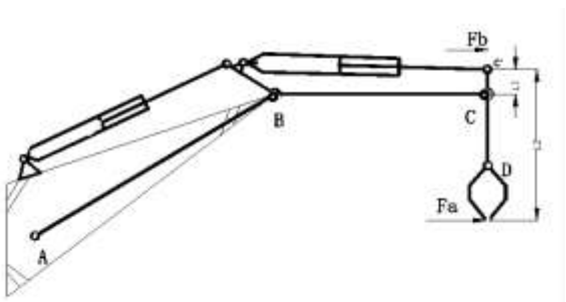

Figure 6 arm hydraulic cylinder force situation

3.2 The short arm design

3.2.1 Determination of the position of the C 'position of the short arm

The movement of the wrist is limited by the movement of the arm cylinder, where we can design the arm cylinder to fully stretch during the movement and the movement of the arm cylinder through the movement of the C 'point. It is known that the stroke of the arm cylinder is $s = 900mm$ and the length of the arc C1' C2 'is exactly the stroke of the hydraulic cylinder. In the above, it can be seen that the maximum angle at which C 'can move is 120 °, as shown in Fig 7. so that $R = 429.71mm$ It can be seen that the hinge point C 'is 429.71 mm from the hinge point C, and the length of the entire wrist is tentatively 1750 mm .

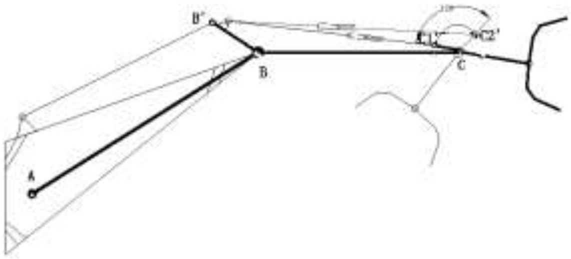

Figure 7 the movement of the point C '

3.2.2 Determination of the arm trajectory

As can be seen from Fig 8, the sum of $h1$ and $h2$ is the maximum distance that the arm and the handle can move scope. $h1$ is the distance between the wrist CD and the center of the hand and the projection in the vertical direction, so $h1$=1782.01mm , and the upper arm is set to 3000 mm , $h2$=3000mm , and the total vertical height $h = 4782mm$. Design of the base is designed on the excavator base, by checking the information we can see that the distance from the base point A is generally 1500 mm, in line with the vertical operation of the handle space -500 ~ 2000 mm.

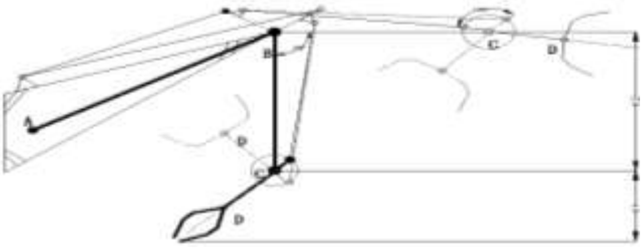

Figure 8 Determination of the arm locus

3.3 The long arm design

3.3.1 Design of the hydraulic cylinder at the boom size

When the relief robot moves the stone in the opposite direction of F_a through the working device, the reaction force of the boom cylinder in the working position shown in Fig 9 is the largest. Here can be introduced in the extreme position of the arm hydraulic cylinder can withstand the maximum pressure F_b . Can be primary $L3 = 400mm, L4 = 3060mm$ .According to the principle of torque balance, we can see $F_a \cdot L4 = F_b \cdot L3$, F_a taken as 15000 N .

Through the calculation and checklist GB / T2348-1993, $D = 90mm$.

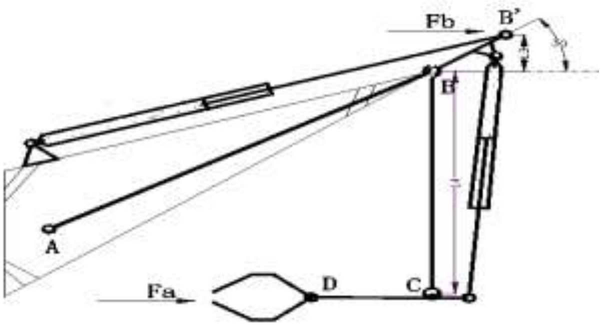

Figure 9 The analysis of arm hydraulic cylinder force

3.3.2 Determination of the position of the B ' position of the long arm

The movement of the arm is limited by the movement of the arm hydraulic cylinder, where we can design the arm cylinder in the course of the movement can be fully extended, and through the B 'point of movement to achieve the arm hydraulic cylinder movement. It is known that the stroke of the boom cylinder is $s = 900mm$ and the length of the arc B1' B2 'is exactly the stroke of the hydraulic cylinder. It can be seen from Fig 10 that the maximum angle at which B 'can move is 90 °, so that R = 573.25 mm . It can be seen that the hinge point B 'is 573.25 mm from the hinge point B.

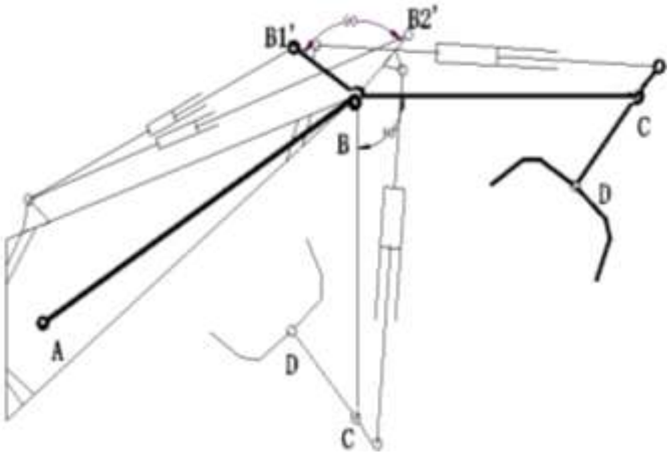

Figure 10 B 'point of the movement diagram

IV. STRENGTH CHECK

As the wrist relative to other parts of the greater force, The article on the wrist at the hinge hole C and its front strength have be checked. The material of the wrist is 45 steel, and the circumference of the two hinges in the wrist model exerts a circumferential symmetry constraint, because the end of the hydraulic cylinder of the handle is rotated around the wrist hinge hole C. Work process is the use of hydraulic cylinder to promote the pin clamping hinge hole, which achieve the grasping action of the handle. While the pressing force is applied to the hinge hole C through the hydraulic cylinder. When the handle is in the closed state, the maximum pressure of the hydraulic cylinder, calculated by the above calculation $F_a = 43857N$, and this time the largest cylinder pressure $P = 22.35Mpa$. The above load is applied to the hinge hole C, as shown in Fig 11.

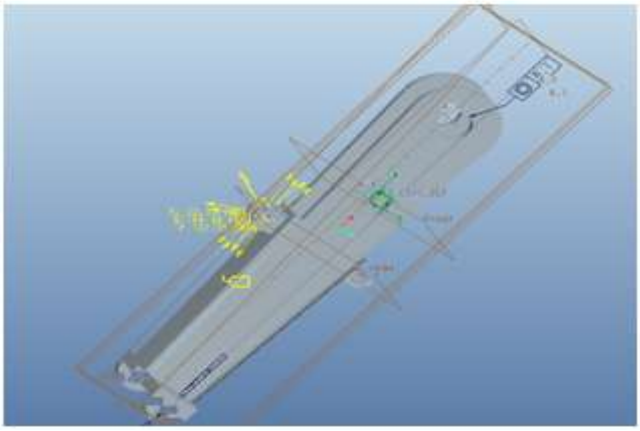

Figure 11 The articulated hole C applied load

As can be seen from Fig 12, the maximum stress of the hinge hole C is about 53.8 Mpa , which is much smaller than the yield limit of the material 335 Mpa , so that the hinge hole is safe. By analyzing the front head of the hinge point, it is possible to prevent the wrist steel from bending due to the excessive load. As shown in Figure 13 below, where the maximum force at 298.7 Mpa , and the choice of material yield limit of 335 Mpa , so the place is safe.

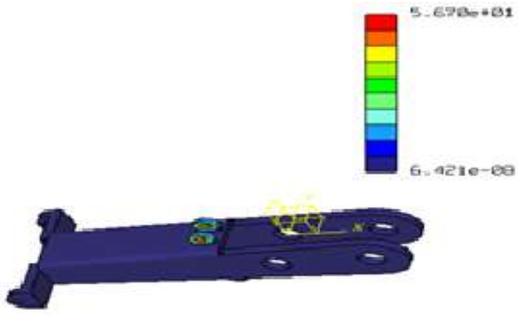

Figure 12 Stress of the hinge hole C

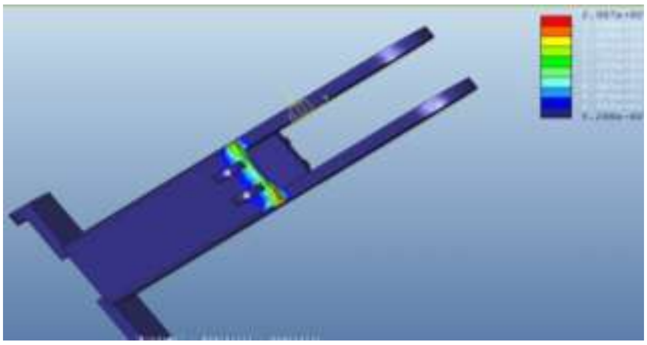

Figure 13 The articulated hole C front stress

V. CONCLUSION

Based on the hydraulic arm of the disaster relief robot, the structure of the hydraulic handle, the long arm and the short arm of the hydraulic arm is designed, the strength of the hinge hole C and its front is checked, which provides the idea for the design of other hydraulic mechanism.

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