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The lifting and separating system for ground maneuvering rescue equipment

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ABSTRACT

At present, the research of our country specific emergency system of ground maneuvering rescue equipment has not been carried out. The field of special mine rescue equipment lacks specific lifting and separating facilities. To solve the above problems, this study innovatively designed a Lifting and separating system that matches with the ground maneuvering rescue equipment. The design of the Lifting and separating system mainly includes the following four aspects: the Lifting control room, Lift arm material section, size of telescopic boom, and the Selection of hydraulic cylinder for telescopic boom. This study uses ANSYS for the research and analysis. In the process of mine rescue, this system can enhance the economy and flexibility of hedge facilities and improve the technology of mine safety emergency rescue in China. The system also has important economic value and social significance for enterprises.

KEYWORDS: lifting and separating system; mine rescue; ANSYS simulation

1. INTRODUCTION

At present, the field of mine special rescue equipment (Liu, 2010) still lacks specific lifting and separating facilities. Large and middle rescue equipment is mostly used in external miniature truck cranes or gantry cranes (Schlick, 1975), which is influenced by the site space and manoeuvrability.

The platform for the Lifting and separating system was designed to solve the above problems. The system design is based on the platform control unit, which has the advantages of being built-in, lightweight, having a simple structure, and convenient operation.

The main purpose of the system is for use in mine rescue. The system has the effect of seismic noise reduction and integrated management and control (Zhang, K.J., 2012), and therefore the built-in platform, independent control room, and the equipment unit can be assembled and separated quickly. This is conducive to the rapid expansion of the rescue platform and rescue construction (Xu and Du, 2009).

2. COMPOSITION OF LIFTING AND SEPARATING SYSTEM

The Lifting and separating system mainly includes four parts (Liu, 1999): hydraulic pump station, boom, control unit, and auxiliary facilities. The hydraulic pump station is in the right side of the rescue vehicle control area and the telescopic boom and crane and other major components with the anchor buckle are on the platform of two high strength steel truss. The structure is stable and reliable. The structure is shown in Figures 1 and 2.

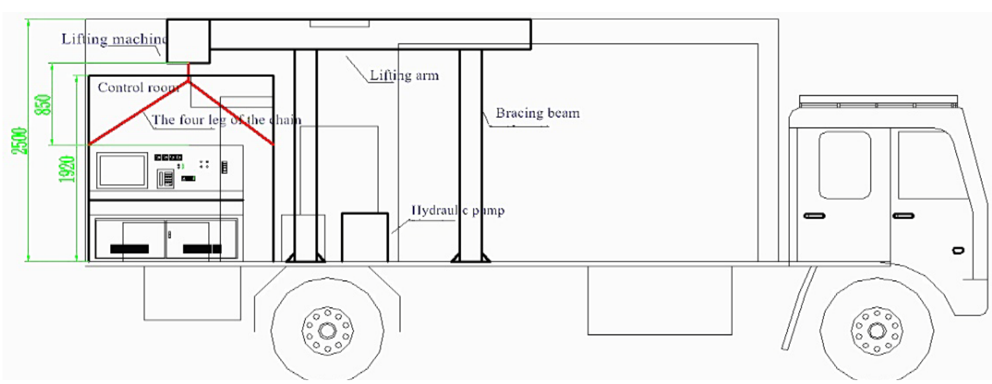

Figure 1: Arrangement of lifting and separating system.

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Figure 2: Assembly and assembly drawings for lifting and separating system.

3. DESIGN OF LIFTING AND SEPARATING SYSTEM

The design of the lifting separation system (Cun and Sun, 2010) mainly includes two parts, namely the lifting and hoisting systems.

3.1 Study on the design of the control room

The system of hanging arm lifting the control room (Lin, 2012) is located on the tail of the platform, weighing about 1 tonne and the load distribution is uniform. The console, locker, air conditioning, and machine weight are arranged around the room, increasing the torque balance. Device specific parameters are as shown in Table 1 and equipment layout is as shown in Figure 3.

Table 1: Size, weight of the control room equipment.

Part	Dimensions (length * width * height)mm	Weight kg
box body	inside (1670*1920*1850) outside (1750*2000*1920)	500
Operating table	750*1500*1200	125
Air conditioner (Inside)	680*190*240	7
Air conditioner (Outside)	620*200*440	24
File cabinet	900*390*1700	25
Chair	800*320*500	10
Fire Extinguisher		16
Others		
Total		707
Remarks	Design of lifting the maximum load of 1000kg	

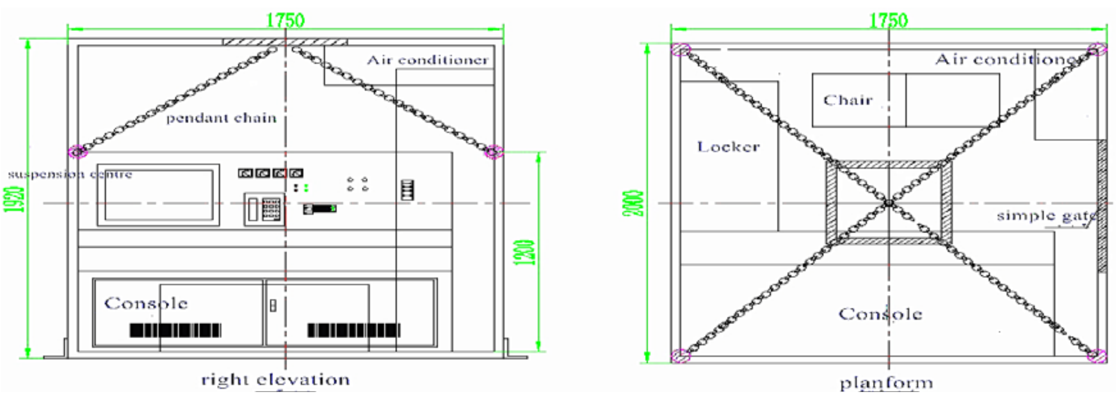

Figure 3: Design of control room layout.

In order to test the scientific nature and rationality of the design of the control room and to ensure the safety of the experiment (Liu, 2005), a 2 min driving test is carried out. For the test to achieve the desired effect the load control room layout should be reasonable and the design requirements of hoisting should be met.

3.2 Determination of material section of boom

(1) Selection of telescopic boom material

At present, the material of the lifting arm is made up of various types of alloy steel and low carbon steel. Heavy lifting appliances mainly use high strength low carbon alloy steel, and the medium and small cranes adopt 16Mn. Considering the cost and the design of the lifting weight is not large, the crane material design uses 16Mn.

(2) Section of the telescopic boom

The main body of the main arm uses 16Mn material. Overall the choice of materials and structure of the design considers safety and the economic applications of the principle (Huang and Ou, 2011). It is optimal to reduce the weight of the boom and to achieve the overall optimization of the suspension arm and the whole system performance (Chen, 2012).

3.3 Determination of dimensions of telescopic boom

(1) The design of the main and sub arm's length

The design of the main boom length is determined by the basic arm length and the extended length.

$$l_{max}=l_0-(k-1)a+(k-1)l=l_0+(k-1)l' \qquad (1)$$

In the optimization design platforms, according to engineering experience, lap length should be extended to the length of 1/4 to 1/5 for the second section crane arm, and $l'=(0.2\sim0.25)l_i$ for the second section hanging arm.

The second section telescopic boom is fully recovered from the main arm, and there is a long distance C, which mainly is the main arm of the hydraulic cylinder stretching mechanism and the fastening device. This space is often within the range of 0.25-0.44 m. Therefore, the main pair of two arm structure lengths has the following relations:

$$l_i^0=l_{i+1}^0+c-a \qquad (2)$$

The two section telescopic boom, lap length of the second section telescopic boom, and jib is equal to 1/5 of the extended length. The main vice hanging arm joint length and the length of the structure are:

$$l_2''=0.2l;\quad l_2^0=1.2l \qquad (3)$$

$$l_1^0=1.2l+(k-1)(c-a) \qquad (4)$$

(2) Check the length of the main and auxiliary arm

Through the above calculation, we can know that the length of the main arm is satisfied with the length of 4-31, and the length of the second sections can meet the design requirements and engineering use.

$$l_0=l_1^0+a(k-1)\geq 1.2l+(k-1)c=1.2(l'+a)+(k-1)c \qquad (5)$$

According to the above calculations and verification, the vice arm of the section and the length of the relevant surplus: $l_1^0=3.1(m); l_2'=1.6(m); a_2=0.3(m)$

In summary, the boom sections design size and cross section are determined as shown in Figure 4.

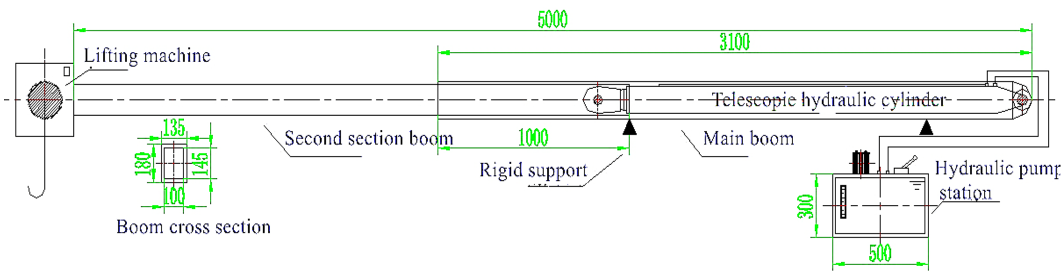

Figure 4: Boom size chart.

3.4 Calculation and selection of hydraulic cylinder for telescopic boom

(1) The inner diameter of the cylinder of hydraulic cylinder

Set the maximum load of the arm Q=1.5 T for the telescopic cylinder to bear the maximum pressure:

$$F_{max}=1.9Q=2.85T \qquad (6)$$

Combined with the practical requirements, the hydraulic cylinder of the allowable working pressure is 5 MPa, D=60.03 mm, combined with the inner diameter of hydraulic cylinder, D=63 mm.

(2) Hydraulic cylinder piston rod diameter calculation

a. Design

Combined with the movement speed of the piston rod, φ =1.33. d=31.38 mm. Combined with the series of piston rod diameter, d=32 mm.

b. Hydraulic cylinder strength test

The platform lift arm is 16Mn, so σ_b is 345 MPa; n is the safety factor and considering the security, the n is 5 after testing the strength of the hydraulic cylinder to meet the design requirements.

c. Hydraulic cylinder stability test

It can be determined when the piston rod size is d=50 mm, the arm is safe and reliable, and meets the strength and stability calculations.

(3) Calculation of the hydraulic cylinder wall thickness and diameter

The platform telescopic hydraulic cylinder wall thickness and diameter to meet the strength requirements under load. D_1=67 mm.

To sum up, we can draw telescopic hydraulic cylinder structure parameters of hydraulic cylinder diameter: 63 mm. Hydraulic cylinder diameter: 67 mm; piston rod diameter: 50 mm.

4. THE FINITE ELEMENT ANALYSIS OF TELESCOPIC ARM BASED ON ANSYS

4.1 Finite element model of telescopic boom

(1) Entity model

The first section is 180*135 mm, the wall thickness is 17.5 mm, the length is 3100 mm; the second section is 145*100 mm, the wall thickness is 10 mm, the length is 2900 mm, the assembly depth is 1000 mm; the material is structural steel, the elastic modulus is 200 GPa, the Poisson's ratio is 0.3.

The geometric model is shown in Figure 5.

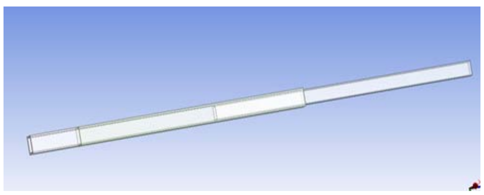

Figure 5: Geometric model of telescopic boom.

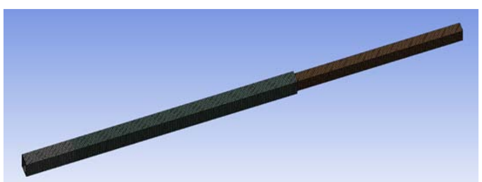

Figure 6: Grid division of telescopic boom.

(2) Unit selection and grid division

The platform lift arm model was built to select the unit. Shell element shell63 and solid45 were selected for the simulation of solid element to choose the unit body belonging to 8 node 6 unit, hanging arm model scale: node number 3201, unit number 41821. Grid divisions are as shown in Figure 6.

(3) Model of the contact of the boom

Because of the telescopic arm, between the main and auxiliary boom depends mainly on the chute and the plate of a lubricated contact force transfer. Therefore, we must deal with the model of the contact of the boom.

(4) Arm loading and constraint handling

The load of the telescopic boom mainly includes: the control room load, steel wire rope, and the supporting force of pull arm. Under the premise of considering the surplus coefficient, the control room load is 1t, as shown in Figure 7. The C is applied to the 9800N surface.

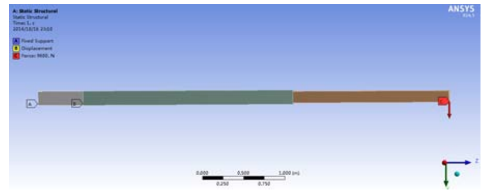

Figure 7: Constraint and load chart of the telescopic arm.

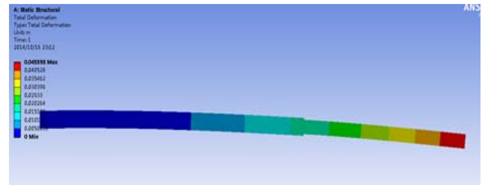

Figure 8: working plan of the telescopic boom

4.2 Analysis of finite element calculation results of telescopic boom

In order to verify the security and reliability of the telescopic boom, the second section of the boom is completely out of the operating conditions for simulation verification.

(1) The overall structure

As shown in Figure 8, the maximum deflection of the structure is 45.6 mm. The maximum stress of the structure is 167.4 MPa, far less than the allowable stress of the material ([σ] =345 MPa), which appears in the first section of the arm frame and the second arm frame. These results are shown in Figures 9 and 10.

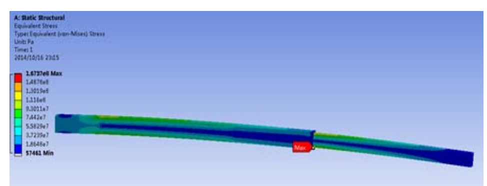

Figure 9: The overall structure of telescopic boom.

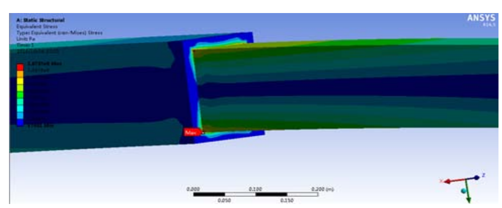

Figure 10: The maximum stress concentration point of the structure of telescopic boom.

(2) The second cantilever crane;

Through Figure 2, we can know that in the 11 section of the arm, the stress concentration is mainly distributed in the junction with the first arm, the intersection of the arm, and the maximum stress concentration is consistent with the overall simulation results.

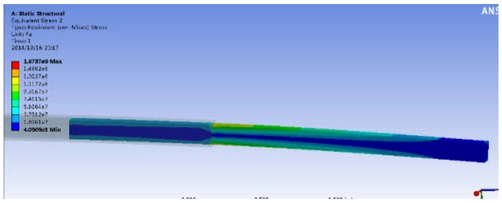

Figure 11: Stress chart of the second cantilever crane.

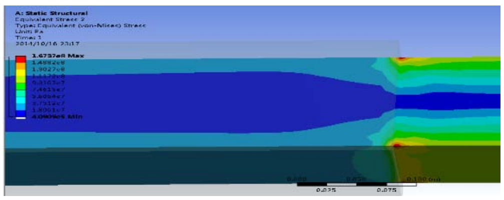

Figure 12: Maximum stress concentration point of the second cantilever crane.

(3) The first cantilever crane

The maximum deflection of the first cantilever crane is 16.8 mm, as shown in Figure 13, less than the overall structure maximum deflection of 45.6mm. The supporting role of the main arm of the hydraulic cylinder is minimal, which in turn verifies the rationality of the hydraulic cylinder structure.

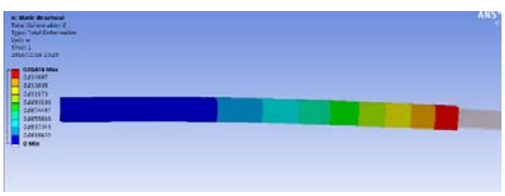

Figure 13: Working plan of the first cantilever crane.

5. CONCLUSIONS

1) According to the uniformity of load distribution, the control room of the crane hoisting system has been designed and is comprised of the console, locker, air conditioning, and outside machines, increasing the torque balance. The lifting point is arranged in the control indoor four beam column side with a special four legged chain sling connected. The field test achieved the desired effect, showing that the load control room layout is reasonable and satisfies the design requirements of hoisting.

2) The design uses rectangular cross sections. The main arm of the main body uses 16Mn as material, and for the four corners of the weld and other stress concentrations, alloy steel is used. This not only optimizes the weight of the boom but also achieves the overall optimization of the performance of the split system of the arm and the whole hoisting system.

3) The telescopic boom is composed of two parts, the main arm and the outer part. The length of the main, sub arm's length, design size, and cross section were determined.

4) Based on the ANSYS finite element simulation, we know that when the two rectangular arms are made of 16Mn material, the section size meets the designing demand, and the maximum rated starting weight is 1 tonne and the extension length is 1.9 m, the strength and stiffness of the arm conforms to the safety requirements. The whole telescopic boom is safe and reliable.

6. ACKNOWLEDGEMENT

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