Paper No. 103

ISMS 2016

Safety and stability of the maneuvering rescue platform

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ABSTRACT
With the continuous developments in the field of mining rescue, mechanical rescue equipment has been growing more complex and automatic, which leads to higher requirement for the safety, stability, and carrying ability of platform foundations. In response to these requirements, the present study designed an overall layout of the maneuvering rescue platform equipment. Upon consideration of the load arrangement rationality of the rescue platform, the humanity and convenience of the on-board equipment function, and the safety of the electric device, the overall layout of the vehicle was divided into two units: the device unit and the control unit. After completing the overall layout design, the security and stability of the platform was verified and analyzed. The results proved that the design of the maneuvering rescue platform met the requirements for the stability and safety of the mine rescue mission. The platform can be quickly deployed over a long distance with suitable mobility and carrying capacity.
KEYWORDS: maneuvering rescue platform; stability; modifications

Once a water permeating accident or other mine gas outburst accident occurs, emergency rescue platforms should arrive in the rescue site and establish temporary rescue command posts in the shortest possible time (Huang and Ou, 2011). The village, field, and hillsides on the way to mine rescues can be difficult to maneuver (Zhang, 2012; Yu, 2000), therefore, the security and stability of rescue platforms is very important.

1. THE OVERALL LAYOUT OF THE MANEUVERING RESCUE PLATFORM

The nature of the maneuvering rescue platform and other specialty vehicle design modifications is basically the same. The main difference is that the ultimate goal of the maneuvering rescue platform design is to reach the rescue site and accomplish the rescue mission. The roads to the rescue site are mostly rugged and complicated to maneuver. Therefore, the vehicles need to be more reliable and stable.

When maneuvering rescue platforms, the characteristics of the on-board equipment need to be considered, including device functions, volume, mass, and many other factors. Maneuvering rescue platforms integrate the air supply system, power supply system, the flow of food supply systems, monitoring, and control communications systems. Once the destruction of the underground system has occurred, the maneuvering rescue platform can provide power, communications, and food for the refuge chamber through the orifice docking device.

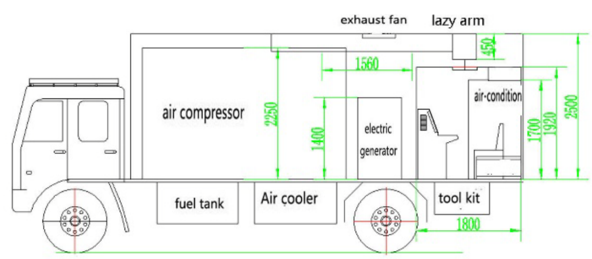

Figure 1: Layout left view of the maneuvering rescue platforms.

The overall layout of the vehicle is divided into two units: the device unit and the control unit. As shown, the device unit is made up of the air compressor, water tanks, generators, transformers, pump station, and most of the power and rescue equipment. The functions of the control unit are controlling communications, electricity transmission, monitoring, and other functions.

2. THE DISTRIBUTION OF LOAD AND THE CENTER OF MASS

In maneuvering rescue platform design, what needs to be considered is the quality of different vehicle equipment, features, and rational layout location equipment. This is necessary to facilitate the operator's quick and accurate control. Intrinsic safety design needs to be performed according to equipment function and reasonable partition. By calculating the distance between the gravity center of the main harness and the front axle of the platform, the relative space position of the vehicle equipment should be reasonably arranged. In order to fully ensure platform

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security, it is necessary to improve the system's practicality and aesthetics (Liu, 1994; Cui, 1986). The calculation is as follows:

1) Establish a Cartesian coordinate system. The origin of coordinates is in the vehicle axle. The extension of the two vehicle axle is the Y-axis and the roof plumb line is the Z axis. Coordinate positive direction is chosen, as shown in Fig.2.

2) The major equipment parameter list is shown in Table 1, including mass and the centroid location, with the relative distance of the axes and the like.

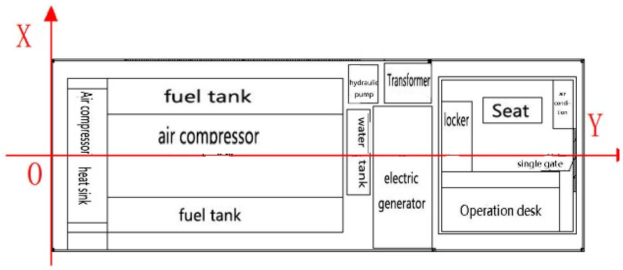

Figure 2: Maneuvering rescue platform x-y coordinate system schematic.

Table 1: Maneuvering rescue platform centroid position of major equipment and the quality of their list.

NO.	moment	Parts Names	Weight G/Kg	Centroid Y-axis distance/mm
1	F_1	air compressor	4500	1950
2	F_2	electric generator	540	4465
3	F_3	transformer	460	4525
…	…	…	…	…
n-2	F_{n-2}	lazy arm	310	5297
n-1	F_{n-1}	control board	125	5735
n	F_n	water tank	600	3903
	F_{sum}	Sum	8750	2460.98
NO.	moment	Parts Names	Centroid height Z/mm	Centroid X-axis distance /mm
1	F_1	air compressor	1875	0
2	F_2	electric generator	1480	-465
3	F_3	transformer	950	886
…	…	…	…	…
n-2	F_{n-2}	lazy arm	3032	0
n-1	F_{n-1}	control board	1260	-697
n	F_n	water tank	1680	105
	F_{sum}	Sum	1608.49	5.48

3) From Table 1, the total equipment weight is G=8750kg. Fukuda Ollin CTX5200 vehicle chassis parameters are used to allow a maximum carrying capacity of G_{max}=1T>G, which is within the allowable load range, and not overweight.

$$F_{rear} = \frac{\sum_{i=1}^{n} F_i Y_i}{L} = \frac{32371456}{5200} = 6225.28\text{kg} \qquad (2-1)$$

$$F_{front} = F - F_{rear} = 8750-6225.28 = 2524.72\text{kg}$$

(2-2)

$$F_{left} = \frac{F \times (\frac{B}{2} + X)}{B} = \frac{7966715}{1810} = 4401.50kg$$

(2-3)

$$F_{right} = F - F_{left} = 8750-4401.5 = 4348.50\text{kg}$$

(2-4)

According to the above calculation:

Platform chassis front axle maximum load $F_{front\ axle}$=3250 kg>F_{front} = 2524.72 kg, rear axle maximum axle load $F_{rear\ axle}$ = 6750 kg>F_{rear} = 6225.28 kg. The overall design of the platform weight does not exceed the original parameters of the permissible range of the vehicle, and it was in line with the safety requirements. On the other hand, after the platform modifications, load was close to full capacity. It is important to note the use of usual safe driving tactics, and to avoid the use of emergency brakes. While in the latter part of the platform design, what needs to be further considered is the streamlining harness, use of lightweight materials, optimized chassis, and other measures to increase the flexibility of the platform.

3. LONGITUDINAL STABILITY

In order to ensure the platform with security and stability, longitudinal stability studies of the modified platform were performed.

The rescue platform utilized the Fukuda standard commercial chassis without any modifications, so there were no parking brake problems. The only major considerations for longitudinal stability of the platform analysis are the longitudinal tipping and longitudinal slippage (Zhang, 1997; Shuichi, 1981), as shown in Figure 3.

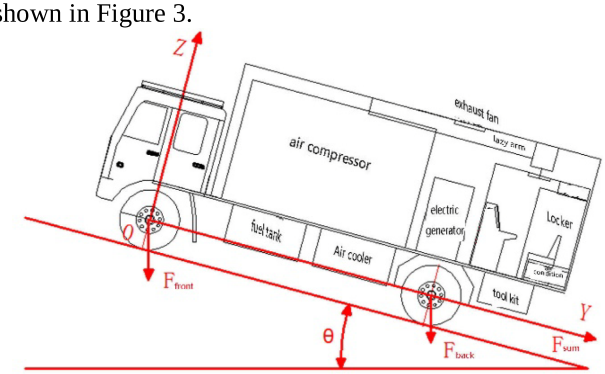

Figure 3: Maneuvering rescue platforms longitudinal stability diagram.

Verification is calculated as follows:

Platform maximum sideslip angle is calculated as:

$$\theta_{\text{slip}} = \arctan\frac{Y \times \phi}{L - Z \times \phi} = \arctan\frac{2460.981 \times 0.5}{5200\text{-}1608.49 \times 0.5} = 15.64^{\circ} \quad (3\text{-}1)$$

When climbing, the maximum slope angle is calculated as:

$$\theta_{\text{downhill}} = \arctan\frac{L - Y}{Z} = \arctan\frac{5200 - 2460.98}{1608.49} = 59.53^{\circ} \quad (3\text{-}2)$$

When downhill, the maximum slope angle is calculated as:

$$\theta_{\text{climbing}} = \arctan\frac{Y}{Z} = \arctan\frac{2460.98}{1608.49} = 56.83^{\circ} \quad (3\text{-}3)$$

Calculation of the above formula shows that $\theta_{slip}<\theta_{climbing}$, $\theta_{slip}<\theta_{downhill}$, $\theta_{slip}<$Prev θ_{turn}, suggesting that when vehicle instability occurs, sliding phenomenon occurs. However, overturn will not occur, which ensures the platform's longitudinal stability and security. In addition, the results show that $\theta_{climbing}$ and $\theta_{downhill}$ are about four times the θ_{slip}, which shows that the overall vehicle longitudinal conversion is quite reliable. Once sliding occurs, the driver of the maneuvering rescue platform would have enough time to correct for the slide. This ensures the safe emergency disposal.

4. LATERAL STABILITY

The lateral stability of the platform directly affects how the vehicle travels in horizontal centrifugal force. Horizontal centrifugal force is related to the stability of the vehicle state and must be determined in the reliability test and verified as an important platform indicator for road safety. Research on lateral stability mainly includes two aspects: cornering stability and cross slope stability.

4.1 Cornering stability

Analysis shows that the platform has a tendency to tilt outwards when subjected to centrifugal force around a corner.

The centrifugal force on the platform is inversely proportional to the turning radius, but is proportional to the speed.

If the platform corner has a minimum radius of R_{min}=6.25 m (chassis factory parameters). then cornering limit speed when the platform slides is calculated as:

$$V_{slip} = \sqrt{\text{g} \times \phi \times R_{\min}} = \sqrt{9.8 \times 0.5 \times 6.25} = 5.53\text{m/s} \quad (4\text{-}1)$$

Cornering limit speed when platform rollover occurs is calculated as:

$$V_{turn} = \sqrt{\frac{R_{\min} \times b \times g}{2Z}} = \sqrt{\frac{6.25 \times 9.8 \times 1930}{2 \times 1608.49}} = 6.06\text{m/s} \quad (4\text{-}2)$$

In the formula, car gage b =1930mm (chassis factory parameters).

It can be seen from the above calculation process, $V_{turn}>V_{slip}$, that platform lateral stability is reliable when cornering. Also, the surplus quantity of the V_{turn} and V_{slip} is relatively low, indicating that although safety of the platform is not a problem, there is room for improvement in stability. Vehicle rollover under conditions of the limit cannot be ruled out, because of the high speed or too-small turning radius. The best way to improve stability is to reduce the overall centroid height Z of the platform to achieve $V_{turn} >> V_{slip}$ over the state, which is also an important aspect of late platform optimizing.

4.2 Cross slope stability

Cross slope stability, with respect to the platform, is measured by:

$$\frac{\text{b}}{2 \times Z} > \phi \quad (4\text{-}3)$$

$$\frac{\text{b}}{2 \times Z} = \frac{1930}{2 \times 1608.49} = 0.60 \quad (4\text{-}4)$$

According to the results, 0.60>Φ = 0.50, therefore, the design with the cross slope is safe. However, in order to better ensure the safety of the platform, the platform should be loaded with a reasonable arrangement: for example, compact integrated devices should be chosen and the equipment should be put in a lower position. The purpose of reducing centroid height by the above means is to increase the driving safety of the platform.

4.3 Wind resistance

Platform modified equipment for the purpose of cooling and elimination of flue gas is placed in the roof of the vehicle platoon, which indirectly increases the wind age area of the vehicle with increases of platform height.

The Bernoulli equation shows:

$$w_p = \frac{v^2}{1600} \quad (4\text{-}5)$$

Consider that the work conditions of the platform are no more than 5 wind strength, and therefore take 5 wind speed (v = 10.7 m/s) for the authentication parameter in formula 4-6:

$$w_p = \frac{10.7^2}{1600} = 0.0072 kN/m^2 \quad (4\text{-}6)$$

The roof platform exhaust fan height is about 0.25 m, and the wind area is about 0.45 m^2, so the exhaust fan wind torque:

$$F = w_p \times 0.25 \times 0.45 = 81 \mathrm{kg} \cdot \mathrm{m} \quad (4\text{-}7)$$

The overturning moment platform can afford:

$$F_{platform} = \mathrm{F} \times \mathrm{Z} = 8750 \times 1.61 = 14087.5 \mathrm{kg} \cdot \mathrm{m} \quad (4\text{-}8)$$

From the above calculation, G=F=8750 kg, Z=1.61 m, F<<$F_{platform}$. This shows that the drag generated by the wind on the exhaust fan for emergency rescue platforms is negligible. The platform has wind resistance and the ability to resist overturning.

5. CONCLUSIONS

A platform was modified to ensure the uniformity and reasonable load distribution as much as possible. The platform had good stability when loaded, with uphill and downhill angles being within the maximum angle limit.

Platform rollover would not occur when loaded and cornering within the maximum allowed angle. The platform would be permitted within the maximum load under conditions of full and full fittings.

The cooling fan on the roof caused an increase in the wind area due to the increased height, however the wind resistance was reduced. The platform has wind resistance and the ability to resist overturning.

6. ACKNOWLEDGEMENT

It is with great pleasure that we acknowledge the generous financial support of the Hebei central energy Fengfeng Group, the National Natural Science Foundation of China (project number: 51474017) and Natural Science Foundation of Xinjiang Uygur Autonomous Region of China (2014211B013).

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