Research on Vulnerability of Multifunctional Military Cabin

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***Abstract*—The study of vulnerability is an important basis for the evaluation of warfare damage in China's weapons and equipment, and it is also an important part of the research on the viability of weapons and equipment in China. In this paper, according to the damage level principle of the aircraft, the damage level of the multi-functional military cabin truck is established. Then we used the damage tree analysis method and Solid works 3D software to construct an equivalent damage model, and identified the key parts and weak points of the cabin car. This will have certain reference application value for further research on the vulnerability and equivalent target of multi-functional military cabins.**

Keywords-Military Cabin Truck; Vulnerability; Damage Tree Analysis Method; Solidworks Modeling

I. INTRODUCTION

The research on the vulnerability of the target is an important part of the research on the survivability of weapons and equipment, and also an important basis for the evaluation of the damage of weapons and equipment. The research on the vulnerability of multi-functional military cabin trucks has certain complexity, mainly in the fact that the cabin trucks are generally large in size, complex in internal structure and have a large number of electronic components and electronic circuits, and usually perform tasks with important equipment. Strengthening the research on the vulnerability of multi-functional military cabin trucks has an important impetus to improve its operational survivability and speed up the development and improvement of weapon systems.

In this paper, the damage tree analysis method and Solid Works 3D software are used to construct the equivalent damage model to determine the key parts and weak points of the cabin truck.

The main purpose of this paper in the analysis of the damage tree analysis method is to find the combination of causes and causes of undesired events related to the cabin system, that is, to find all the damage that caused the top event (cavity damage). The mode, and thereby determine the fatal component of the shelter truck corresponding to a certain damage level at a certain mission stage.

II. DAMAGE TREE AND 3D MODELING ANALYSIS METHOD TO STUDY THE VULNERABILITY OF MULTIFUNTION CABIN

A. Division of kill level

Considering the theoretical similarity of the damage level of the multi-function cabin truck and the aircraft and armored vehicles and its own particularity, the article draws on the domestic and international classification standards for aircraft killing levels, The damage of military cabin cars and their systems or components is divided into four levels based on different mission phases:

- KK-level killing: The standard for this level is when the cabin car is hit; the critical components, systems or cabins have been devastated and have lost the need for repairs. It usually caused by: an explosion of a projectile or missile warhead inside or outside an aircraft cabin, an explosion of a fuel tank, or an explosion caused by an engine.
- K-level killing: The standard for this level is when the cabin car is hit; its critical components, systems or cabin cars have been severely damaged and must be returned to the original factory for overhaul.
- A-level killing: The standard for this level is when the cabin car is hit, serious damage to its key components, systems, or damage to multiple parts of the cabin truck, without the ability to repair on site and return to the factory, this or recent mission must be abandoned.
- B-level killing: The standard for this level is when the cabin car is hit, damaged parts of the sidecar can be replaced or repaired immediately without affecting the execution of the mission. These components are either spare parts that can be replaced in the field after damage, or non-lethal parts that can be replaced or repaired in the field.

B. Analysis of Structure and Function of Square Cabin Car

For different military cabin cars, not only the internal mechanism and equipment are arranged differently, but even the external structure is different. For example, the role of some models of cabin cars is mainly battlefield command, military reconnaissance, and some are mainly used for battlefield treatment and military communications, so the division of subsystems is not the same. Through the comparative analysis of several types of multi-function cabin trucks, the multi-function cabin system can be divided into four systems according to different functions: Motion systems, electrical systems, control systems and cabin systems. One by one is as follows:

Motion system: It is the most important structural part of the whole vehicle. Its mission is primarily to provide the power required by the vehicle and to ensure that the vehicle has good overall mobility and maneuverability. It generally includes a power system, a transmission system, a brake system, and so on.

Electrical system: It includes the power supply system and the air supply system. The power supply system provides power support for the task of completing electronic countermeasures for the cabin truck. The gas supply system and air compressor included in the gas supply system provide a power source for the expansion of the cabin.

Control system: Generally, it can be regarded as composed of automatic control system and manual control system according to control mode. The main function of the system is to control the movement of the cabin and the extension and operation of the cabin during the execution of the mission.

Trunk system: Depending on the type of cabin, the functions performed by each are different. Such as the field surgery cabin car, the whole vehicle is modified from the off-road chassis, and the vehicle is equipped with a remote satellite system, which can realize video therapy and remote expert consultation; The car is equipped with a ventilator, an anesthesia machine, and a multi-function electric knife. The rear part of the compartment can be connected to the pre-operative preparation tent, self-guaranteed power supply, water supply, and is not affected by the outside world.

It can be seen from the above analysis that the multi-functional military cabin has a large body and a complicated structure, It consists mainly of four systems, each consisting of many subsystems, each of which contains a large number of components (subsystems). Due to space limitations, the paper takes a model field medical cabin car as an example, and gives its system structure, as shown in Figure 1.

Due to the complexity of the modern operational environment, the target must have many corresponding functions to successfully complete its combat mission. For multi-purpose cabin cars, the cabin trucks must complete their combat missions, and should also have storage, maneuvering and battlefield medical functions.

The various functions of the cabin truck are obtained through coordinated operation of a corresponding set of physical components. The diversity of the function of the sidecar determines the complexity of the structure of the car. It consists of many functional systems, which in turn consist of many sub-function systems and components, which in turn are made up of parts.

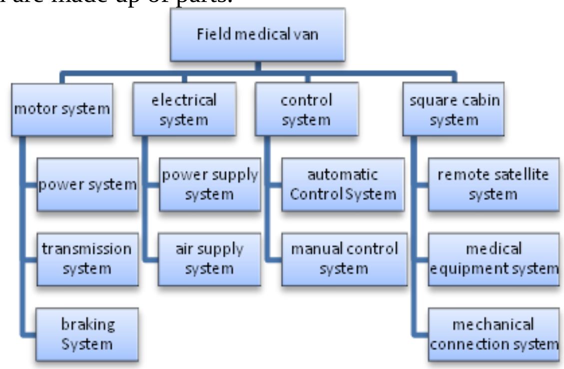


Figure 1. Structure frame of a model field medical cabin car

C. Task Phase Division

As mentioned earlier, the mission phase is the basis for the assessment of the vulnerability of the cabin. Therefore, before the damage of the cabin car is studied, there should be a clear division of the mission phase of the launch vehicle. The stages of the multi-function cabin trucks performing the tasks and the tasks undertaken at each stage are generally:

Their systems or a component is divided into four levels based on different mission phases:

- Standby phase: completing tasks such as storage of medical equipment in the cabin before the battle and concealment of the vehicle body;
- Maneuvering phase: completing tasks such as tactical maneuvers from the rear position to the medical position;
- Operational stage: complete tasks such as cabin opening, extension, and power supply;

The main functions completed in each task phase are shown in the figure 2:

Figure 2. Division of the task phase of the field medical cabin truck

D. Analysis of Damage Mechanism and Damage Mode Phase Division

1) Damage mechanism

In addition to personnel targets, military cabin vehicles are mostly composed of mechanical components and electronic components, there are also a small number of optical components and flammable and explosive components (such as fuel, oxidizer), these components have protective layers such as tank casings and square casings. Therefore, all kinds of ammunition damage the protective layer mainly by destroying the protective layer, which in turn destroys the structure of the component and causes its function to be lost. Specifically, the damage mechanism of mechanical components can be subdivided into: complete fracture, crack, plastic deformation, etc. For electronic and optical components, high-intensity electromagnetic pulse signals and strong light generated by blasting can cause failure and component destruction. For electronic and optical components, high-intensity electromagnetic pulse signals and strong light generated by blasting can cause failure and component destruction.

2) Damage Mode

The damage mode of the target is the form of damage caused by the target being hit by the ammunition; it is related to both the damage element of the ammunition and the target structure and material properties. There are mainly the following types of multi-functional military cabin car damage modes: Mechanical damage, short circuit of electrical equipment, fire or explosion of flammable materials, casualties, etc. Due to the diversification of the target damage mechanism and the complexity of the target structure, the target damage mode is also diversified. Taking the engine as one of the components of the cabin power system as an example, the damage patterns observed from the test are: oil passage obstruction, oil leakage, breakdown of the combustion chamber, breakdown of the compression chamber, etc. These are just a few of them, and there are many other damage modes for other subsystems and components. It should be pointed out that different damage modes may cause the same functional loss to the target. For example, the target movement speed is reduced by 30%, which may be caused by the destruction of the lubricating oil system, or may be caused by other components such as the combustion chamber or the oil passage, but they are the same degree of damage to a certain function of the target.

E. Damaged Tree and Solidworks Modeling

1) Damaged Tree Modeling

It can be seen from the above analysis that the multi-functional military cabin truck has a complicated structure and numerous components. Due to space limitations, the following section will be based on the analysis of the structure and damage mechanism and mode of a multi-functional military medical cabin car system, and introducing the specific process of building a damaged tree for a multi-purpose military medical cabin car system. The KK-level damage tree of the cabin system is given as an example.

The sidecar system can be considered to consist of a transporter system, a cabin system and a radiation protection system. As long as one of these three subsystems is damaged, it will cause damage to the cabin system. Therefore, they are logical OR relationships.

The damage event of the three subsystems of the powertrain, electrical system and chassis system of the transport vehicle system is a logical OR relationship. This means that as long as one of the subsystems is damaged, it will cause damage to the transport vehicle system. Especially for the power system, the entire cabin will lose all mobility when it is damaged. If the damage is serious, it may cause the engine to catch fire or even explode.

In the cabin system, it consists mainly of three subsystems: the square cabin, the CT control room and the CT scanning room. The square cabin is mainly a rectangular tank made of carbon fiber composite material. This new material has high specific strength, good design, good structural stability and fatigue fracture resistance, and the characteristics of absorbing wave stealth. It has been widely used in equipment lightweight. The square cabin is in a closed state during the maneuvering and standby phases, and its outer dimensions like long, wide and high are: 3500×2100×1900mm; When the cabin is in the state of running medical phase, it is stretched to both sides, and its outer dimensions like long ,wide and high are: 3500×5800×1900mm; And the CT control room and the CT scan room are in the cabin.

As long as any one of these three subsystems is damaged, it will cause damage to the cabin system. They are a logical OR relationship. However, their CT control room and each subsystem below the CT scanning room do not affect each other, which is a logical relationship.

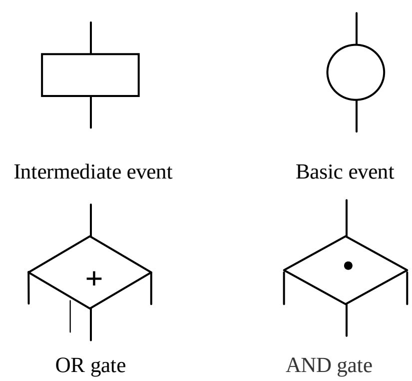
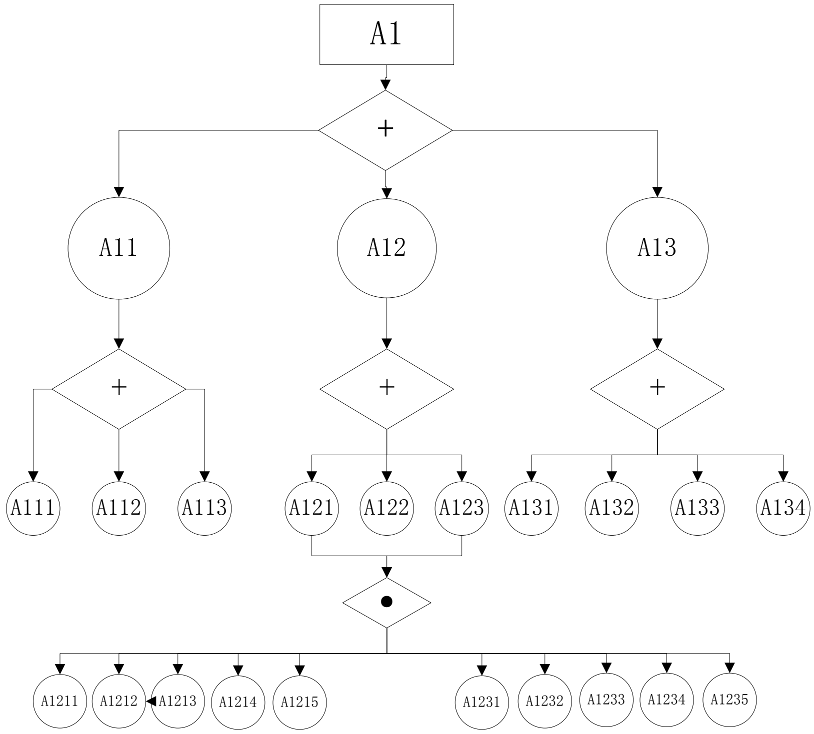


Figure 3. Description of the symbol meaning of the damage tree

Finally, the radiation protection system is mainly composed of a plurality of lead plates of different thicknesses disposed on the side walls of the cabin. The military medical cabin cars of the model do not have lead plates at the top and bottom of the cabin. This is because the medical cabin system is different from the CT examination room in the hospital when it is in use, and there are no staff at the upper and bottom, therefore, the lead plate at the position can be omitted, which not only reduces the total weight of the cabin, increases maneuverability, but also saves manufacturing costs. Any one of them will be damaged by the radiation protection system as long as any one of the lead plates is damaged, So there is a logical OR relationship between them.

Through the above analysis, the damage tree model of the KK-level damage of a certain type of field medical cabin car system is shown in Figure 4. The meanings of the symbols used are described as follows:



A1 is a KK-level damage to the medical cabin system, A11 is damage of the transport vehicle system, A12 is damage of the cabin system, A13 is damage of the radiation protection system, A111 is the damage of the power system, A112 is the electrical system damage, A113 is the chassis system, A121 is the CT control room damage, A122 is the cabin cabin Body damage, A123 is the CT scanning room damage, A131 is the front bulkhead lead plate damage, A132 is the rear bulkhead lead plate damage, A133 is the left bulkhead lead plate damage, A134 is the right bulkhead lead plate damage, A1211 is the image collection workstation damage, A1212 is damaged by image processing workstation, A1213 is medical display damage, A1214 is damage of viewing light, A1215 is damaged by diagnostic report printer, A1231 is damage of scanning bed, A1232 is damage of CT device, A1233 is damage of CT vibration support, A1234 is Cabin partition damage, A1235 is the control room partition damage.

Figure 4. Structure of the KK-class damage tree in the field medical cabin

2) Three-dimensional structure model of a cabin car

It can be seen from the above that according to the damage tree model, a certain type of field medical sidecar has been divided into three systems: transport vehicle, cabin and radiation protection. The transport vehicle system is the foundation, and its main function is to provide power and carrying cabins. From the point of view of the mechanical structure, it can be simply divided into a cockpit and a chassis system. The two mechanical systems are assembled into one unit through a complicated connecting mechanism.

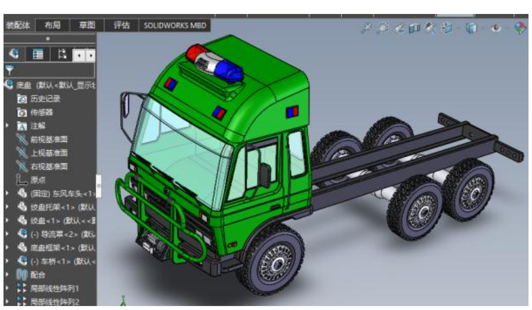


Figure 5. Three-dimensional simplified model of the transport vehicle

Referring to the existing literature, the simplified Solid-works 3D model of Figure 5 is established as shown.

As mentioned above, the transport vehicle system is the foundation, and the medical cabin system is the core of the whole vehicle. Because all kinds of medical equipment are loaded inside the cabin, all the medical assistance functions are carried out. Due to space limitation, and also mentioned above, the various subsystems of the medical cabin are not repeated here. According to the original size, the simplified three- dimensional model of the cabin is shown in Figure 6 below:

Finally, the three-dimensional model of the entire medical cabin car after the assembly of the transport vehicle and the cabin is shown in Figure 7 below:

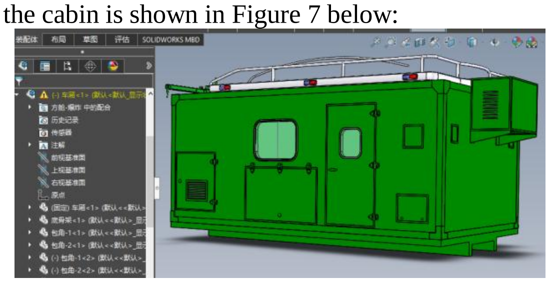


Figure 6. 3D simplified model of the medical cabin

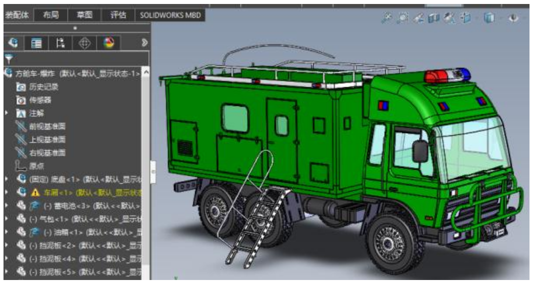


Figure 7. 3D model of a model field medical cabin car

F. *Analysis and Determination of Fatal Components*

The bottom event of the damaged tree is the root cause of a certain level of damage to the cabin, so the components associated with the bottom event are the deadly parts of the damage level. According to the established three-dimensional model of the medical cabin car, the strength and rigidity of the deadly parts of the analyzed cabin can be studied one by one, which makes it possible to optimize the mechanical structure of its deadly components.

For example, the damage tree built in the above example consists of 17 components or subsystem damage events such as chassis, engine and cabin interior equipment. For the cabin system, The damage events of 11 components such as the cabin, the CT control room CT and the scanning room are the cause of the KK-level damage of the cabin system, they are the deadly components (subsystems) of the KK-class damage to the cabin system. But for the 10 components of the image acquisition workstation and image processing workstation in the CT control room and CT scan room, the damage to the cabin system can only be caused when all damage events occur. Therefore, it is not a fatal component for a single cabin interior, but the subsystems they make are fatal subsystems. As can be seen from the above analysis, by analyzing a damaged tree of a certain type of medical cabin car corresponding to a certain damage level and Solidworks 3D model, we can determine the deadly parts of this damage level.

III. CONCLUSION

The vulnerability assessment of multi- purpose field medical cabins is of great significance for studying the survivability of the cabin system and the evaluation of combat damage. Based on the research results of the vulnerability of aircraft and armored vehicles at home and abroad, the damage of the cabin trucks, systems and components is divided into four damage levels of KK, K, A and B based on the task.

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REFERENCES

[1] Pei Yang, Song Bieng, Li Zhanke. Study on basic methods of aircraft vulnerability assessment [J]. Journal of projectile and arrow guidance, 2004(02):70-74.)

[2] Liu Sen,Chen hong, Zhou Zhixuan, Ren Leisheng, Huang Jie. A quantitative calculation method for vulnerability of armored vehicles [J]. Journal of projectile and arrow guidance, 2012,32(03): 217-219+226..

[3] Yang Shirong, Liu Wei, Wang Caihong. Vulnerability assessment and modeling of missile launcher [J]. Journal of missile and missile guidance,2006 (02):41-44.

[4] Xiao Shiyun, Feng chengliang, Chen wen, Liu Yuping, Liu zongwei, Cheng Wei. Integrated modeling of target vulnerability [J/OL]. Journal of orderequipment engineering: 1-7 [2019-10-16].

[5] Paul A. Chircop,Bernard J. Kachoyan. Damage accumulation and probabi- lity of kill for gun and target engage- ments[J]. Naval Research Logistics (NRL),2018,65(2).

[6] Wang Haifu, Li Xiangrong, Liu Zhixiong, Feng Shunshan. Vulnerability modeling and Application analysis of armored vehicles [J]. Journal of projectile and.

[7] Wang Xueli. Overview of the development of military cabin technology in China [J]. Special purpose vehicle, 2016(03):68-72.

[8] Pan Wenjuan Liu Zhenchun, Wu Xinwen, Ze Haocheng, Li Jianyu . The field medical team operating shelter vehicle or application difficulty and countermeasure of infection control [J]. Journal of south China national defense medical journal, 2018, 32 (9) : 646-648.

[9] Zou bin. Discussion on the concept of target vulnerability and related theories [J]. Sichuan architecture,2016, 36(04):134-137..