

Application of Composite Materials in the Fire Explosion Suppression System

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Abstract: In order to lighten the weight of the special vehicles and improve their mobility and flexibility ,the weight of all subsystems of the whole vehicle must be reduced in the general planning. A fire explosion suppression system is an important subsystem for the self-protection of vehicle ,protection of crews and safety of a vehicle. The performances of the special vehicles determine their survival ability and combat capability. The composite bottle is made of aluminum alloy with externally wrapped carbon fiber; it has been proven by a large number of tests that the new type explosion suppression fire extinguisher made of such composite materials applied in the special vehicle has reliable performance ,each of its technical indexes is higher or equal to that of a steel extinguisher ,and the composites can also optimize the assembly structure of the bottle ,and improve the reliability and corrosion resistance. Most important is that the composite materials can effectively lighten the weight of the fire explosion suppression system to reach the target of weight reduction of the subsystem in general planning.

Key words: protection performance; fire explosion suppression system; composite materials; explosion suppression fire extinguisher; weight reduction of the subsystem

1 Introduction

According to the analysis of military experts ,a future war will be one that simultaneously involves army ,navy ,air-force ,space-warfare and electronic attack. However ,as far as the characteristics of modern war are concerned ,ground combat and conflict will exist for a long time ,the main assault force for ground combat will still be army armored forces whose main combat equipment will depend on tanks and armored vehicles.

The performances of tanks and armored vehicles concentrate on four respects: fire ,mobility ,protection and information. The performance of protection is also newly called as an integrated defense system which covers the technology of stealthy ,laser-alarm ,suppressing observation and fire explosion suppression ,response-armor and extra-short distance anti missile etc. so it is clearly seen that the fire explosion suppression system is an essential part as well.

Nowadays ,in some countries ,light metals and poly-

meric materials have been used to replace the traditional fabrication technology ,and plastics ,synthetic materials and ceramic materials have been successively applied in tanks and armored vehicles manufacture. Aluminum alloy armor ,aluminum alloy turret seat ,titanium alloy creeper tread and plastics rolling element etc ,and the tank loading wheels in some countries is even made by a hard die ,so it is seen that the weight issue of tanks and armored vehicles has been put into attention by many countries.

The weight of the explosion suppression fire extinguisher in the fire explosion suppression system also brings a certain influence on mobility of the tank and armored vehicle and the application of composite materials in the fire explosion suppression system bases on such a situation. If each sub-system weight can be reduced with ensuring its performance ,the decrease of the combat weight of tank and armored vehicle will be more effective; the mobility of tank and vehicle is always restricted by its weight ,and then the reduction of the whole vehicles' weight will obviously improve its mobility and enhance its combat capability.

2 Status quo of explosion suppression fire distinguisher

The fire explosion suppression system is an essential part of the special vehicle. It can start the distinguisher by the electric signal from a control box via detecting and sensing a fire condition and realize automatic fire-extinguishing and explosion suppression. So the system is also called as fire explosion suppression device , which is one type of fire distinguishing device , it responses extremely quickly in quenching the fire and in suppressing the explosion induced by ammunition. During the design of the Merkava tank directed by General Tal , father of Israeli Tanks , who put forward the particular design concept of Protection first and Crew's survival first. Merkava series main battle tanks got their a real trial by combat in the Middle East War , and they are unique tanks that cherish survival of the crew best. Destroy and killing effect caused by burns and explosions in the hit tanks is usually called Secondary Effect. Special vehicles are equipped with an effective fire explosion suppression systems that can prevent tanks from Secondary Effect and significantly improve the survivals of crew in the battle field. From detecting fire to quenching it , this system needs a very short time , it can suppress the explosion of oil-gas mixture in a fighting compartment caused by heat jet flow in 50 ms and restrict the pressure brought by the explosion in 0.1 MPa , and then the skin burn of the crew can be limited below 1 degree , so it realizes the function of fire explosion suppression. The automatic fire explosion suppression devices have already been equipped in the up-to-date main battle tanks; the survivals of both tanks and crew have been greatly improved. In the Israel-Lebanon War ,1982 , all of the Israeli Merkava tanks were equipped with the automatic fire explosion suppression devices , some of them were penetrated by anti-tank weapons , but the casualties of the tanks were only half of the other , and none of the crew was burnt to death. Such a case cannot be found in the past large scale tank wars.

Survival is an integrated war art performance which

includes two sides of tanks and crew. With diversifying of the anti-tank weapons and improving for their powers , tank designers of every country have put the survival of tanks on the prominent position. In the designing process of Leopard 2 tank , military party has made twenty demands for tactical performance , of which the survival of crew is the top one. And in this respect , Merkava tanks are the most superior. They are known as the tanks with three quarters of the vehicle weight for protection , and weight of the common tanks 50% , the protection system includes fire explosion suppression device.

At present , the explosion suppression fire distinguisher widely used in the special vehicles is drawing welded one made of steel whose over-all performance is at the domestic leading level. Its advantages are that price is relatively lower , and the body strength is higher , but the manufacturing process is more complicated with the defects of many weld seams ,easy leakage and worse corrosion resistance of steel. And the obvious defects of the steel distinguisher is that it is too heavy to be processed and used. And it is more important that the manufacturers of the other sub-systems put their attention to the integrated performances of the system , hower the weight loss of the system is ignored , so the results come that the light-type tank is not light at all and can not satisfy the operational demands of strong power , speed and flexibility for light equipment , and to some extent , it may forfeit the combat chance and cause loss of crew and equipment , and even decide whether the war is won or not. So it is seen that the decrease of sub-system weight is very necessary.

3 Features of the new type composite materials explosion suppression distinguisher's body

The inside liner of the distinguisher is made of aluminum alloy , and the distinguisher is externally wrapped with carbon fiber. Such a distinguisher is called an allover carbon fiber wrapped aluminum liner gas bottle. Composite materials are used in manufacturing

pressure vessels recently in a more advanced manufacture process that is applied in 863 China National Research and Development Projects. The liner is made by high grade 6061 aluminum alloy through the process of stamping , drawing , heat-treating , CNC spinning shut , internal surface treating and machining etc. The liner has even wall thickness , high precision of shoulder and bottom and strong consistency. And its inner surface is anodized and has better corrosion resistance. The external wrapped layer is made of imported top quality carbon fiber and epoxy resins etc. and is processed by CHC wrapping and high temperature curing. Allover carbon fiber wrapped aluminum gas bottle(See Figure 1) .

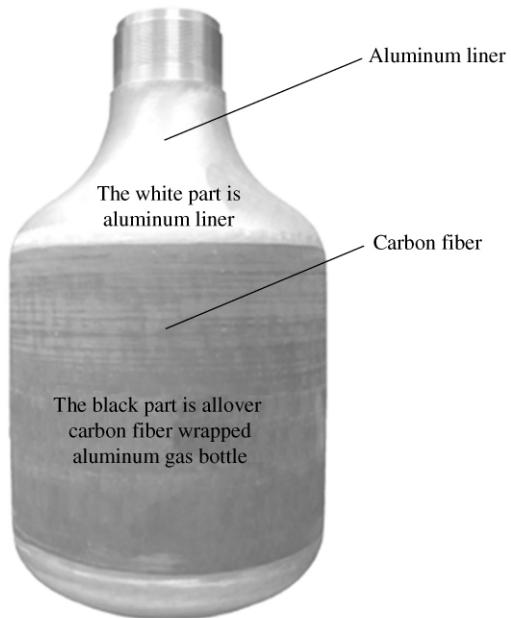


Figure 1 Allover carbon fiber wrapped aluminum gas bottle

The composite materials bottle has more excellent performance. It has higher working pressure , larger volume of gas , 50% reduction in weight , better corrosion resistance , fine isolation and shock absorption and high safety. The bottle is widely applied in the fields of fire-control , mine , chemicals , metallurgy , power , natural gas , auto etc. , but it has not been used in national defense equipment yet. With the development of tech develops , the fire explosion suppression technology in our country , we will keep the

advantage in the world.

The bottle is overall a seamless structure without weld process , so it can reduce leakage points , and its mouth is linked with external parts by threads that can both increase the link reliability and optimize product structure. The excellent aluminum alloy's corrosion resistance is better for the fire explosion suppression system to be stable under an extreme environment. The density of aluminum alloy is 2.7 g/cm^3 , which is only 35% of that of steel , so it can reduce the bottle weight greatly and satisfy the demands of the system.

4 Proposal and development of the new explosion suppression fire extinguisher

The new explosion suppression fire extinguisher is proposed as a domestic one has been developed , the project prescribed that the combat weight of the whole vehicle should not exceed design parameters to improve the vehicle's mobility , flexibility and to realize the quick response and air lift requests. However , the main weight of the special vehicle concentrates on several parts of the engine , chassis , fire system , FCS and armor protection , and it is very difficult to reduce the weight of these parts , because they are the important supports for attack , mobility and protection. As to present technology , the weight reduction of these parts means lowering the integrated combat capability and protection ability , clearly it is , not in accord with the designing concept and developing trend for modern military equipment. In order to realize the design target of the combat weight , nothing can be done except the weight reduction of a sub-system. Hence Chief Engineer Unit assigned the research task which requires weight reduction of the sub-system under the condition without lowering the tactical target and performance. For the fire explosion suppression system , two particular norms are proposed that the weights of two type extinguishers should be designed , respectively , within 10 kg and 12 kg.

Since the wholly carbon fiber wrapped aluminum liner gas bottle has been widely applied in many fields , so it is a preferred plan to design and develop a new ex-

plosion suppression fire extinguisher based on this gas bottle. On market investigation ,original prototype design and its pilot manufacturing , the advanced technology of composite materials have been successful applied in the explosion suppression fire extinguishing through two years' test. In two specifications of the new products ,the 2.7 kg extinguisher passed the new product type-fixing examination by the National Review Board in May ,2009 ,up to now ,these products have been widely used in the third generation main battle tanks and multiple-model wheeled armored vehicles. The other one is that of 4 kg ,which is equipped on the most advanced domestic digital self-propelled artillery ,and it has been type-fixed on the equipment in July ,2007. The use of the new fire explosion suppression products has provided necessary safeguards for enhancing the mobility , flexibility , protection and integrated combat capability for our special vehicles.

In the process of these two new extinguishers ,several techniques and targets ,such as weight reduction of main parts ,manufacturing of the bottle ,connection of jacket and bottle ,installation of fixed block ,and the detection of start time and injecting time etc. are the essence crucial items for product developing.

4.1 Achievement of weight reduction target

The main path for weight reduction is that the steel bottle is replaced by that of aluminum alloy ,and then extended to other parts ,such as jacket ,boot cap ,flange and supported flange; all of them are originally made of steel ,and are replaced by aluminum alloy ,so the weight of the products is greatly decreased. However ,according to " the lighter ,the better" rule under the promise of satisfying the performance demands ,we have studied the details of the product ,for instance ,machining several holes on the end-face of the jacket and grooves on the surplus part along the circumference of the flange and its likes. Such nuances also can reduce certain weight. The final weights of the two products are reduced from the original 14 kg and 17 kg ,respectively ,to 9 kg and 11 kg ,1 kg lower than that of design request.

4.2 Manufacture of the bottle and its mechanical properties

The original steel bottle is fabricated by a split stretch and welding process; the oil hydraulic press and gas shield arc welding can meet the needs of machining. When the material is changed into aluminum manufacturing alloy ,the process of split stretch and welding can not be used ,because the welding process of aluminum does not meet the needs of the bottle's working pressure. Based on much processing analysis and gradual completeness of the procedure program ,aluminum plate stretch is finally adopted ,and then shut by digital hot spinning machine to finish the original fabrication of the bottle. Carbon fiber is selected from the imported materials and the wrap is completed by the special independent *R&D* digital carbon fiber wrapping production line.

After the steel bottle the replaced by the overall carbon fiber wrapped aluminum gas bottle , the main problem facing is whether the bottle burst pressure can reach the design value of equal to or more than 16 MPa ,which is an important target related to safety. The pressure capability of aluminum is theoretically lower than that of steel. How can the bottle meet the needs of burst pressure? Firstly ,the design of bottle wall thickness is considered. But it is a very contradictory concern that the wall thickness is possibly thinner for weight reduction ,hower ,the burst pressure should be guaranteed. After much experiment with different wall thickness ,the final wall thickness is designed as 2.5 mm ,only the burst pressure of a-luminum liner can be over 11 MPa through a burst test ,and the pressure can reach more than 22 MPa after the bottle is wrapped by carbon fiber ,the value is over 7 MPa upon the design ,so the bottle can sufficiently satisfy the demand of safety.

4.3 The connection of jacket to the bottle

The jacket is nothing but a nexus. It first connects to the bottle ,then to the boot cap that covers all mechanical parts and electrical elements outside the bottle mouth to protect these parts. The cap and jacket are fixed via screws. The connection of jacket and

boot cap of the steel bottle is completed by a welding process , but the weld process of aluminum can meet the needs of huge impact and vibration caused by the special vehicle operates in the worst condition. Otherwise , the aluminum bottle's surface is wrapped by carbon fiber , so it is impossible to be welded. Since the steel explosion suppression fire extinguisher has been a fixed type product for many years , the design concept has been deep-rooted in the manufacturers' mind , and no solution has been found for a long time. During this period , the design programs of the domestic similar products were taken as reference , every external connection of carbon fiber as parent material is mainly realized by the fixing technology of carbon fiber press wrapping that is equivalent to completing the connections among parts by carbon fiber bundling. If there are not so many greater impacts , such a program can meet the needs. However , the special vehicle is quite different from the common civil one; the vehicle will produce severe turbulence when it runs in an extreme environment , so the product must be guaranteed to keep stable quality under the test of 110 g shock acceleration.

Connection of mouth of the steel explosion suppression fire extinguisher to the jacket via a flange is compct-

ed by welding process , the jacket is a cylinder , so the link of the jacket and bottle can only be realized by welding. Aluminum can not be welded or be bundled by carbon fiber either , so the only solution is to change the form of the jacket and the connection way. As the mind changed ,the restriction of the traditional thinking way has been finally broken. The original cylinder hole of the jacket is alerted into a blind hole , and a thru hole is machined at the central position of an end of the blind hole (See the Figure 2) , and threads are tapped outside the mouth of the bottle , and the central thru hole of the jacket is set in the mouth , and tightly fixed by a lock-nut (See the Figure 3) . Such a connection way has the advantage of simple process ,easy installation and reliable fixation. The link strength satisfies the demand of design.

Such a connection way has another advantage as well , i. e. the carbon fiber shoulder-press oblique wrapping method is not necessarily used , the wrapping can be completed only around the bottle circumference. Such a way not only simplifies the wrapping process , but also beautifies the bottle appearance. This connection has made double effects: not only improving the carbon fiber wrapping quality , but also reducing the wrapping cost.



Figure 2 Jacket structure

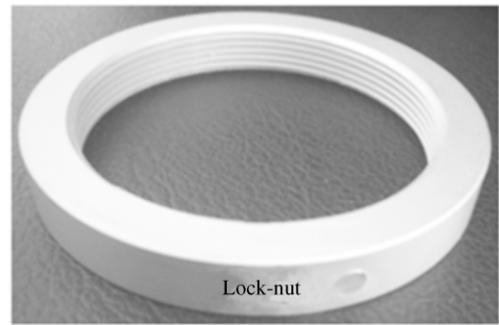


Figure 3 Lock-nut structure

4.4 Connection of fixing blocks

After the solution to the connection of jacket and bottle , a new technological problem is faced. There is a

fixing block on the bottle circumference , its function is to position for the clamp of the extinguisher and to restrict the axial sliding of the clamp. Once the sliding occurs , the extinguisher will drop off to have the

fire explosion suppression system fail , and the extinguisher can not normally work in case it burns occur.

The connection of the traditional steel bottle fixing block is accomplished by a welding process , and the link is so secure that it is not necessary to worry about the dropping of the extinguisher , but the carbon fiber wrapped aluminum bottle can not be welded at all. After much research and argument , the adhesive a bonding method with special adhesive is used for connection , but this simple way is not so reliable so that there are individual droppings after a vibration test. In order to improve the bonding strength , a fastening strip is added to the bottle circumference , and is tightened by a clamp. So the bonding strength of the block is mostly improved and the tightening force of the fastening strip also promotes the link strength of the block and the bottle. Experienced with many tests , it is shown that such a connection way can satisfy the target demands upon impact and vibration , and realize the extinguisher's installation.

4.5 Detection of start time and injecting time

The technical indexes of the new extinguisher made of composite material should be tested according to the requirements upon the designing , developing and type-fixing. In the tens' test items , the start time and injecting time are two important indexes. It is directly related to the realization of the fire explosion suppression function whether the start time and injecting time can be within the specified period.

The start time and injecting time are the parameters of millisecond grade , they last so instantaneously that no manual time keeping way can be used actually ,so the detections must be done by an advanced detecting device. The start time and injecting time of the type-fixed steel extinguisher were recorded by a white-black film high speed camera , the start time and injecting time can be calculated from the film images. But because such apparatus are too old to be eliminated , and there is no special agent for detecting the start time and injecting time domestically , the injecting test becomes another problem.

However , ours is a university with military connection

and we are informed via the Alumni Association that a weapons testing center in Northeast China may be able to carry out such detection. One of the detecting tasks of this center is to capture the speed ,track and distance of bullets and cartridges. In the detecting process , a high-powered telescope is used to trace records , and an advanced GS-233 color high speed digital recorder is applied to collect the images , provide evidences for the tactical targets of new products. Both bullets and cartridges are running so fast that their speeds can not be recorded by naked eyes , but if the advanced recorder is used , the record can be accomplished , and the data needed will be attained from the observation , analysis and calculation of the images recorded. And this function is a reliable support for detecting the start time and injecting time of the explosion suppression fire extinguisher.

However ,this center has never detected the start time and injecting time of the explosion suppression fire extinguisher before. Two injecting tests have failed. It was analyzed by both military and local experts that there is a key technique that has not been in conform of the request ,namely ,in the moment when the electric signal is sent to the extinguisher ,the high speed camera can not read it out ,only the process of detonation and injection can be detected. There is no start-up moment record ,therefore there is no way to calculate how long it may take that the electric signal is sent and the extinguisher is detonated , i. e. the start time. In order to solve this technical problem ,a controller was specially developed. This instrument sends an optical signal to the high speed recorder while it sends an electric signal to the extinguisher ,thus ,the recorder can write down the moment when the start electric signal is sent and the moment when the LET is lit ,that is the beginning of the start time. So the beginning of the start time can be found in the slow release of the images ,and then the time point of the electric squib detonated is obtained ,and the explosion image for electric squib detonation can be identified. The time point of the squib detonation is the time when the extinguishing agent begins injecting; the process of the extinguishing agent injection

is so clear that it is easy to find the time when the injection ends up. The period of beginning and ending of the injection is the effective injecting time that we expect. It is shown by the Detection Report Data that both the start time and the injection time have reached the design requests. This product has been recognized by users with its special selection of materials and structure design , has been authorized for the product National Patent (ZL200620090594.0) . Assembly and connection way of main parts (See the Figure 4) .

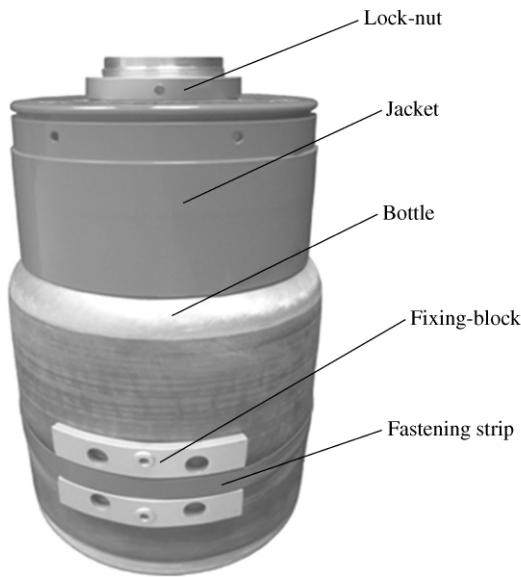


Figure 4 Assembly and connection way of main parts

5 Prospect of fire explosion suppression system for special vehicles

The success of developing a new explosion suppression fire extinguisher provides a variety of selection plans for domestic special vehicles , especially for those that have requirements for combat weight , such as the light-duty tank , airborne vehicle , infantry fighting vehicle and explosion proof vehicle etc. Although there is no local or a large scale war in short term , regional wars are inevitable. The wars in some areas are even more intensively frequent , the worldwide anti-terror situations are more prominent. As the main forces of ground assaults and fights against terror , tanks and armored vehicles will be in a dominant position for a long time , so , in the future , the fire ex-

plosion suppression device will still play its unique role in protection.

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Brief Biographies

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