Diagnosis of Ammunition Failure Based on Analysis of Influencing Factors

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Abstract. Ammunition is a special product widely used in warfare, and its reliability and quality directly affect the level of combat readiness training of troops and determine victory or defeat on the battlefield. Therefore, it is of great military significance to study the failure of ammunition and improve the reliability of its usage. In this paper, the failure modes of ammunition products are studied, the theoretical methods and tasks of failure diagnosis are analysed, the realisation of each analysis technique is summarised, while the influencing factors are summarised, and opinions and suggestions are put forward for the work related to ammunition failure.

Keywords: ammunition failure, diagnostic analysis, failure factors

1 Introduction

With the development of ammunition products towards remoteness, intelligence, dexterity and precision, the technical level of ammunition products is becoming more and more advanced and the cost of materials is becoming more and more expensive, thus causing the economic loss caused by ammunition failure to increase significantly [1]. Therefore, it is necessary to increase research efforts on problems related to munitions failure. Early diagnosis and analysis of suspect munitions can, firstly, reduce the recurrence of similar failures in products or equipment, thus reducing economic losses and improving product quality; secondly, provide information, directions, ways and methods for technological development, technical transformation and scientific and technological progress; thirdly, provide a reliable scientific and technological basis for determining responsibility for accidents and revising and formulating product quality standards, which has important strategic and practical significance.

2 Tasks of failure diagnosis and factor analysis

The diagnosis of munitions failure should cover the entire life cycle of the product, from the beginning of the product design to its end of use or disposal [2]. It is therefore

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important to carry out the systematic diagnosis of products, solve specific problems and analyse the causes and mechanisms of munitions failure, as far as technical capabilities and practical conditions allow. This helps to provide a reference for avoiding or minimising munitions failure, eliminating the potential risk of failure and ensuring the proper functioning of munitions to the greatest extent possible. Although the objectives and significance of failure diagnosis and analysis vary from one objective to another, the ultimate goal is the prevention of failure [3]. Diagnosing the failure of a munition requires an analysis of the failure mode, a summary of the causes and mechanisms of failure, and an analysis of the extent to which each component of the munition system contributes to the failure, in conjunction with the influencing factors.

2.1 Predicting failure factors

Since munitions products are make-or-break products and cannot be repaired once they have been used, failure analysis of munitions products should include a prediction procedure that covers all phases of the product's life. Prediction is a prerequisite for failure diagnosis and analysis. Failure tree analysis (FTA), for example, is one of the most effective methods of analysis for improving the reliability of weapon and equipment systems. It can be used in the research phase to analyse the failure of a design solution and to prevent the failure of a munition. Using this analysis method, important factors affecting failure can be warned in advance, so that improvements can be made at the beginning of the design phase to avoid errors and reduce the rate of defective products and the probability of subsequent failures[4]. Using the Failure Mode Effects and Criticality Analysis (FMECA), ammunition products are diagnosed and warnings are given for the parts of them that are more hazardous, so that the design can be optimised.

2.2 Analysing the causes of failure

Failure modes should be analysed to diagnose the causes and mechanisms of failure based on the munitions failure problems that have occurred. Furthermore, specific failure phenomena should be observed and analysed to determine the type of pattern, and the root cause should be analysed by examining the failure process and mechanism to avoid the risk of recurrence.

2.3 Collecting and recording information

Information is supposed to be collected and recorded in a timely manner for each ammunition failure event diagnosed at each stage. Each ammunition failure diagnosis and improvement should be considered as a process of information collection and experience accumulation. The establishment of an information base helps to take timely and effective measures in the face of failure occurrences, minimising the occurrence of failures and reducing economic losses. Furthermore, it is necessary to analyse and organise the relevant information into a form that can be easily retrieved and utilised. The establishment of a database of failure events throughout the life of the munitions product will be of great benefit in ensuring the timeliness and effectiveness of the diagnosis of munitions failures and will help to eliminate or reduce the occurrence of failures.

3 Methods of failure diagnosis

3.1 Theoretical methods

The process of diagnosing ammunition failures should adhere to scientific and rational principles, with the following main approaches:

3.1.1 Systems analysis.

This method is used throughout the life of a munition product. It combines the structure of the munition itself with the manufacturing environment to form an integrated system for the diagnosis of failure, both in terms of the condition of the munition itself and the impact of the environment on the munition.

3.1.2 Statistical method.

This method is a way of extracting valid information from data by analysing and summarising it. Correct statistical analysis is a prerequisite for decision making. Reasonable use of statistical methods to analyse data on ammunition failure cases can summarise the failure pattern of various types of ammunition and predict the failure trend to a certain extent [5]. Then, reasonable and feasible suggestions can be provided at the beginning of munitions product design to improve the scientificity and feasibility of decision making in munitions work and reduce the probability of failure occurring. At the same time, when the failure occurs, the results of historical statistical analysis will also effectively help workers to quickly and accurately diagnose the failure.

3.1.3 Deductive inductive method.

This method derives general laws for the development of new things by inductive reasoning from general things. The application of this method to ammunition products is to study patterns of failure at various stages, usually in combination with statistical methods.

3.2 Classification of ammunition failure

Ammunition failures can be classified by function and causation as inherent to a single product and as a group failure of a group of munitions in use; causative failures consist of component failure, part failure, assembly failure, potential failure and environmental failure.

3.3 Diagnostic techniques for munitions failure

3.3.1 Failure tree analysis.

This is a top-down analysis of the causes, starting from the undesired event and dissecting the basic events that led to the failure. Because the direction of analysis is from result to cause, the shape of the mind map is like a tree upside down, hence the name Failure Tree Analysis. The failure tree analysis method is now widely used in various problems in society. In the failure diagnosis of ammunition products, the identified failure event is ausually used as the starting top event, combined with possible influencing factors such as environment and human beings, to create a failure tree analysis model and use the deductive method to rank from top to bottom. The basic steps are: comprehensive understanding of the munitions product, identification of the top event, analysis of the top event, calculation of the probability of the top event, and identification of the significant event. Failure tree analysis is a theoretical approach to failure diagnosis. During the analysis process, it is important to note that the operator must be an experienced professional, as the analysis process is complex and prone to errors and requires rigorous logic. Secondly, the failure tree analysis method needs to start at the beginning of the design and run through the whole life cycle of the product, repeating itself over time and as conditions change. The disadvantage is that it is more difficult to quantify the human error.

3.3.2 Hierarchical analysis method.

It is a method for doing quantitative analysis of non-quantitative time in systems engineering, and is systematic and practical in nature. It can make people's thought processes hierarchical through objective descriptions, and is therefore often used to analyse complex systems containing a large number of inter-constraints. When applied in the field of ammunition products, the first step is to establish a hierarchical analysis structure, a step that determines whether valid analysis results can be produced. Before establishing the structure, it is important to have a clear understanding of the failure mode, and to clarify the factors, number and scope of failures, the interconnections and affiliations between the various procedures. In the next step, the factors that cause failure are grouped together and categorised according to their common characteristics, after which the common characteristics between them are used as influencing factors in a new level. The factors in the new level are then treated using the same grouping as in the previous level, and so on until a single top factor is formed. The ultimate goal of the hierarchical analysis method is to determine the weights of each decision scheme and to give consistency indicators for judgement by combining the weights as a basis for decision making. The weights can be determined using the weighted arithmetic mean integrative judgement matrix method, the weighted arithmetic mean integrative ranking vector method, the optimal transfer matrix method, the weighted geometric mean integrative judgement matrix method, etc.

4 Main influencing factors

4.1 The development process.

Problems with the design solutions developed generally include defects such as unreasonable structure, inappropriate choice of materials and inadequate verification, making the munition potentially failure-prone.

4.2 The production process.

The quality of the raw materials used in the production process, the level of processing, the actual parameters of the individual parts (e.g. physical condition, mechanical properties, electrical parameters, etc.) can all affect the quality of the munitions product and cause failure.

4.3 Service process.

During transport and loading and unloading, ammunition can accumulate static electricity due to vibration and friction. For cases where no anti-static protection measures are taken on transport equipment and ammunition packaging, static electricity can affect product performance or even cause accidents when it reaches a certain level. At the same time, damage to ammunition can be caused by a single vibration, which can be cumulative and have a serious impact on the quality of the ammunition.

4.4 Storage process.

In the storage process of ammunition products, the effects of temperature, humidity and external forces on ammunition are more obvious, and there are many factors that can trigger the failure of ammunition. For example, in offshore areas, ammunition is often stored in conditions with high temperature, high humidity and hypersaline. A non-compliant environment or faulty sealing equipment can cause the viscosity of the coating on its surface to drop or be lost. Or chemical changes to the internal powder can prevent the full effect of the powder when burning. These conditions may lead to insufficient chamber pressure, changes in ballistics, reduced accuracy of weapon fire, or outright dangerous situations such as blow-ups.

4.5 The process of use and maintenance.

In the course of use, the lack of routine maintenance and irregularities, personnel irregularities or problems with the structure of the weapon's ammunition supply can cause the ammunition casing to be crushed, deformed or damaged, resulting in changes in the chamber volume. The space in which the powder burns differs from standard conditions can also cause changes in the combustion of the powder and changes in the chamber pressure. It may also be a factor in the failure of the ammunition.

5 Conclusions

For failure analysis to be sustainable and effective, it requires the work itself to be characterised by self-improvement and continuous progress. With the passage of time and the development of manufacturing technology, environmental changes lead to a constant evolution of failure factors, so it is necessary to constantly improve and enrich diagnostic techniques in practice and adjust the weighting of factors in the analysis system to avoid disconnection with the development of manufacturing technology. In addition, it is necessary to establish a professional failure analysis system, attach importance to information exchange, and establish a failure information database to achieve resource sharing. Avoiding the inadequacy and limitations of the technical strength of individual departments can effectively promote the development of failure analysis work.

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