Engineering Failure Analysis 96 (2019) 130–141

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Failure criterion analysis and reliability assessment in process of cartridge ejection

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ARTICLE INFO

Keywords:
Ejector
Failure criterion
Parametric simulation model
Reliability assessment

ABSTRACT

Case ejecting device is one of the most important devices of a tank, whose performance influences the working performance of a tank directly. This study focuses on the failure criteria analysis and reliability assessment of the projecting process of an ejector. Firstly, the failure mechanism of projecting process is studied and the condition of cartridge case can't be thrown out of the window occurs frequently. Secondly, the simulation model of projecting process is established by using the LMS Virtual Lab, then, it is validated by mathematical model. Then, the failure criterion is established by considering the trajectory of cartridge case's mass center and the size of window. The expression of up and down range of cartridge case is got. Finally, reliability is assessed based on the simulation model. The torque generated by torsional springs and the angle of collector are the two main factors which impact the performance of ejector, so the failure boundary and the relationship of the two factors are also calculated by this model. By using the assessment of reliability and failure boundary of main factors, the performance of projecting process of ejector can be improved in practice

1. Introduction

Case ejecting device is used to gather the cartridge case abandoned by artillery and project the cartridge case out of the window of tank. In the process of projecting, the cartridge case hits window and can't be projected out of the window occur frequently, which will impact the normal work of an ejector even the war power of a tank further. So there is an important meaning of studying the performance and assessing the reliability of projecting process of an ejector.

There are few research on the reliability assessment of the projecting process of a case ejecting device. He Lei et al. [1] simulated the elastic ejection process of some elastic ejection mechanism of automatic weapon and established its virtual prototype with the help of software ADAMS. Kang Yanxiang et al. [2] made a computer simulation on cartridge case throwing process of an automatic weapon with FEA method in order to gain the extraction force more accurately and simply. By use of topological structure analysis, based on some certain simplifications, and according to dynamic modeling theory of multi-rigid-body, Zhang Ziqiu et al. [3] established the virtual prototype of the ejector by means of ADAMS software and performed the dynamics simulation test. Though there are few studies on case ejecting device but there are lots of research on the other mechanical failure problems, which can be used as references for this study. Such as Shu-Xin Wang et al. [4] developed a model for the determination of the impact of the stochastic behavior of model parameters on the dynamic response of a system. T.Warren Liao [5] developed an integrated database and expert system for identifying the failure mechanism of mechanical components. Hui Wang et al. [6] developed a hybrid experimental simulation system for mechanism motion reliability by using the LMS Virtual.Lab and Monte Carlo method. Huan Pang et al. [7]

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https://doi.org/10.1016/j.engfailanal.2018.10.003
Received 30 January 2018; Received in revised form 30 September 2018; Accepted 1 October 2018
Available online 02 October 2018
1350-6307/

studied the failure mechanism analysis and reliability assessment of the aircraft slat. Wei Guo et al. [8] analyzed the functional principle and functional hazard analysis for a landing gear cabin door lock mechanism and concluded that the unlocking function of the lock mechanism is the one at most risks.

In the past few decades, many reliability analysis techniques have been developed. The first-order reliability method(FORM) [9,10] and the second-order reliability method(SORM) [11,12], which are based on finding a single most probable point(MPP)in the failure domain, may wrongly assess the safety level in case of multiple MPPs. The Monte Carlo simulation (MCS) technique [13,14] is a basic reference approach and is widely used. However, for the implicit limit state models where the finite element model (FEM) analysis is employed to obtain the output, the MCS method is infeasible due to the large computational cost. Based on MCS, the importance sampling (IS) method [15,16] is developed. In order to reduce the calls of limit state functions, especially for the FEM analysis, some approximation methods based on the meta-models are proposed including quadratic response surfaces [17,18], neural networks [19], support vector machines [20] and Kriging [21]. Among these metamodels, Kriging is an exact interpolation and it provides not only predicted values in any points but also estimations of the local variance of the predictions. The applications of Kriging to structural reliability problems are rather recent. Romero et al. [22] compare Kriging with polynomial regression and finite-element interpolation on progressive lattice samplings with analytical functions. Kaymaz [23] proposed a method to perform structural reliability analysis and compared it to classic response surface methods. B.Echard et al. [24] proposed an active learning reliability method combining Kriging and Monte Carlo simulation. Leigang Zhang et al. [25] proposed an advanced Kriging method for efficiently analyzing the structural reliability. Zhili Sun et al. [26] proposed a new learning function to update design of experiment of Kriging based reliability analysis method.The traditional reliability assessment methods of mechanism should base on large number of tests, which is very time-consuming and expensive. But, by the rapid development of computer simulation technique, the kinematic simulation of ejector can be got by virtual prototype technology. Firstly, this paper analyzes the failure modes of an ejector with the help of FMEA and focuses on the analysis of situation that cartridge case can't be thrown out of the window. Then, the dynamic model is built in the simulation software LMS to conduct the reliability analysis and it is validated by a mathematical model. In order to access the reliability of ejector, the failure criterion is built. Finally, based on the simulation model, reliability and failure boundary of main factors are analyzed. The results of this study will be helpful for the use of ejector in practice.

2. Working principle of the ejector

The ejector is mainly composed by six parts: shell, cartridge case collector, collector actuator, projector base stop plate, torsion spring cartridge and sabots, which is shown in Fig. 1 in detail.

After projecting, the cartridge case squeezes out three sabots and enters into the collector, then the collector actuator takes the collector to projecting location with some specified angle. Then, the valve element of electromagnet takes back and torsional springs released. With the torsion generated by the released torsional springs, the cartridge case can be thrown out of the window of the tank. The working principle is shown in Fig. 2.

3. Failure modes and failure mechanism analysis

In applying FMEA method to the ejector mechanism, three potential failure modes are obtained: (1) the cartridge case can't get into the collector; (2) the cartridge case can't get out of the collector; (3) the cartridge case can't be thrown out of the window. Among the three potential failure modes, the condition of cartridge case can't be thrown out of the window occurs frequently.

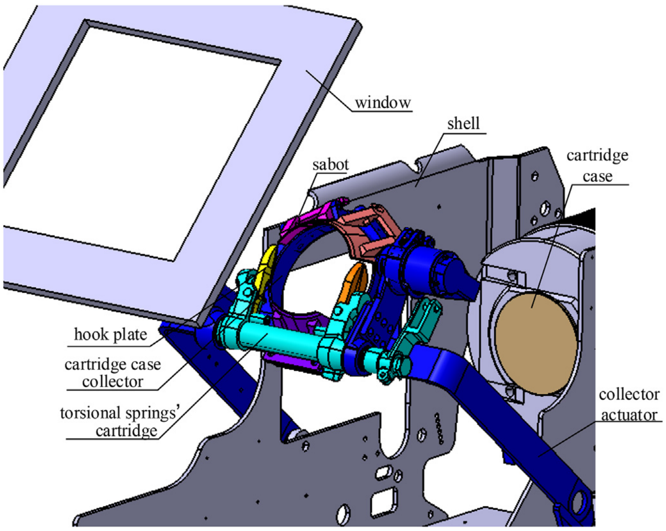

Fig. 1. Diagram of ejector mechanism.