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Review

Numerical and experimental failure analysis of rifle extractor

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ABSTRACT

The purpose of this article is to present a research methodology used to determine the causes of mechanical damage of a cartridge case extractor in a newly designed 5.56 mm assault rifle. It combines numerical analyses and materials science research. Based on the results obtained through simulation studies utilizing the Finite Element Method, values of local stress concentrations in the case extractor were identified. The paper provides detailed information on the used numerical models and adopted initial-boundary conditions required to carry out computer simulations. Based on the obtained values of maximal principal stress, the authors decided to carry out additional experimental research in order to reveal the cause of extractor damage. An adopted approach was consisted of micro hardness and metallographic analysis of the images depicting the microstructure of the extractor material. There were not observed any negative effects of an extractor heat treatment process on mechanical properties of the extractor material. Additional metallographic tests revealed that the main reasons of extractor failures were structural defects of material used in the manufacturing process of the extractor.

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1. Introduction

Operational reliability and safety are one of the key requirements that are formulated when designing new utility models of small arms and specialized fire support means. The implemented engineering solutions should ensure proper and repetitive work conditions guaranteeing safety of soldiers, regardless of weather conditions and terrain in which combat missions are performed. From the engineering point of view, it is a rather challenging problem. Modern analytical tools combined with experimental tests are essential for determination of the structural imperfections and elimination of possible errors in the early stages of weapon development, before mass production is launched.

Based on the literature review, it can be concluded that this approach, though rarely, has been used for many years by a variety of scientific and industrial R&D centers involved in the weapons technology. V. Y. Yu and others [1] present the results of an attempt to determine the causes of mechanical damage of the M16 rifle bolt. Ozmen and others [2] determine the mechanical properties of an automatic weapon breech bolt assembly under static, dynamic and cyclic loading. Urriolagoitia et al. [3] have focused their research on determination of the mechanical properties of a forging tooling required for formation of the small arm barrels. Numerical studies of both an internal and transition ballistic problem are found in publications [4–10].

Given the number of publications on application of numerical modeling methods in design and testing of new models of weapon equipment, it can be concluded that it is very limited due to the confidential nature of the research [11].

They lack information on essential kinematic and dynamic characteristics of the applied automatics system as well as information on the material specification and a relevant technical guidance.

The authors found that it is useful to present one of the major problems solved using a numerical-experimental research methodology during development of a new, modular small arms system. In the course of laboratory durability tests of a newly designed rifle, a deficiency of the proposed solution of a weapon automatics system was found. As a result of long-lasting shooting with continuous fire with ammunition of domestic production (cal. 5.56 × 45 mm RS cartridge, equivalent to 5.56 × 45 mm NATO cartridge with SS109 bullet), there occurred repeated mechanical damage (breaking) of a case extractor (Fig. 1.1), completely eliminating the possibility of further weapon exploitation. The problem was observed for over a dozen of extractors. In most cases, damages occurred in the frontal part of the body or in the surrounding of the pin hole. Given the random nature of the failure, that occurred either after a few hundred or a few thousand shots, the situation was a serious threat and prevented further field durability tests. Originally, the vulnerable geometrical features of the extractor were modified. Unfortunately, the proposed solution was not sufficient enough. Therefore, it was necessary to take additional measures to identify the causes of mechanical damage of the extractor and to propose a solution to the problem. In order to examine the stress field in the extractor, a relevant numerical study was performed. Two different numerical methods were used during the study: a multibody approach and a finite element method.

Due to the complex nature of the problem, the study was carried out in two stages. The first stage consisted of modeling the weapon automatics system operation using a multibody method, the second one was connected with the examination of the stress field in the case extractor using a finite element method. The characteristics of numerical models, as well as definition of initial-boundary conditions are described in the paper. Based on the obtained analyses results, a conclusion indicating the need for further experimental research including micro hardness test and evaluation of material structure based on metallographic images was formulated.

2. Identification of causes of case extractor damage using numerical modeling methods

New modular rifles are designed according to the modern development trends in the field of small arms. They are gas-operated automatic weapons with a rotating bolt. They also utilize a short stroke piston, which is commonly used by the world's

Fig. 1.1. The main view of MSBS extractor failures occurred during firing.