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Issue Article

Denis Chemezov
Vladimir Industrial College
MEng, Honorary Worker of the Education Field of the Russian Federation, Academician of International Academy of Theoretical and Applied Sciences, Lecturer, Russian Federation
https://orcid.org/0000-0002-2747-552X
vic-science@yandex.ru

Ilya Aleksandrov
Vladimir Industrial College
Student, Russian Federation

Daniel Vasin
Vladimir Industrial College
Student, Russian Federation

Ilya Kuznetsov
Vladimir Industrial College
Student, Russian Federation

Danil Nesvet
Vladimir Industrial College
Student, Russian Federation

Georgiy Politov
Vladimir Industrial College
Student, Russian Federation

Andrey Anfertyev
Vladimir Industrial College
Student, Russian Federation

Nikolay Belun
Vladimir Industrial College
Student, Russian Federation

Aleksey Dyomin
Vladimir Industrial College
Student, Russian Federation

Timur Zhigalov
Vladimir Industrial College
Student, Russian Federation

Danila Zakharov
Vladimir Industrial College
Student, Russian Federation

Oleg Medvedev

Vladimir Industrial College
Student, Russian Federation

Vadim Sitkin
Vladimir Industrial College
Student, Russian Federation

Nikita Solovyov
Vladimir Industrial College
Student, Russian Federation

Denis Suslov
Vladimir Industrial College
Student, Russian Federation

Nikita Sholudko
Vladimir Industrial College
Student, Russian Federation

PREDICTING THE STRENGTH OF KEVLAR WHEN FIRING FROM AN ASSAULT RIFLE

Abstract: *The results of a computer calculation of the dynamic impact of an assault rifle bullet on a 30 mm thick Kevlar sample were presented in the article. Conclusions are made about the strength of Kevlar based on the analysis of stresses in various planes, strain, internal energy and temperature of the material after damage.*

Key words: *Kevlar, dynamic impact, bullet, stress, strain.*
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Introduction

Improving the means of protection against firearm bullets and cold steel strikes is an actual task to reduce the deaths of people. Body armor made of various materials is widely used for mobile protection of a person from firearms. The basis for modern body armor is Kevlar (para-aramid fiber) [1-4].

Kevlar has excellent performance properties. The ultimate strength of Kevlar exceeds the ultimate strength of steel by 5 times. The results of Kevlar dynamic impact tests when firing firearms are presented in a number of scientific papers [5-10].

The article proposes to analyze the state of the damaged Kevlar after being hit by an assault rifle bullet. By setting real conditions, it is possible to perform qualitative modeling of the process and obtain with high reliability the dependences of the stress and strain state of Kevlar on its thickness. Thus, it is possible to predict the effective protection of the projected body armor from the thickness of the component materials.

Materials and methods

The state of the Kevlar sample after being hit by an assault rifle bullet was investigated in the Autodyn software product. A 30 mm wide plate placed on a plane was used as a sample. The sample was fixed along the lower edge of the rectangle. The Kalashnikov assault rifle bullet model with a diameter of 7.62 mm had an initial flight speed of 720 m/s. The interaction of the models was performed using the Lagrange method.

Results and discussion

The simulation results are presented in the Fig. 1 in the form of dependences of stresses, strain, internal energy and temperature of the damaged sample on its thickness.

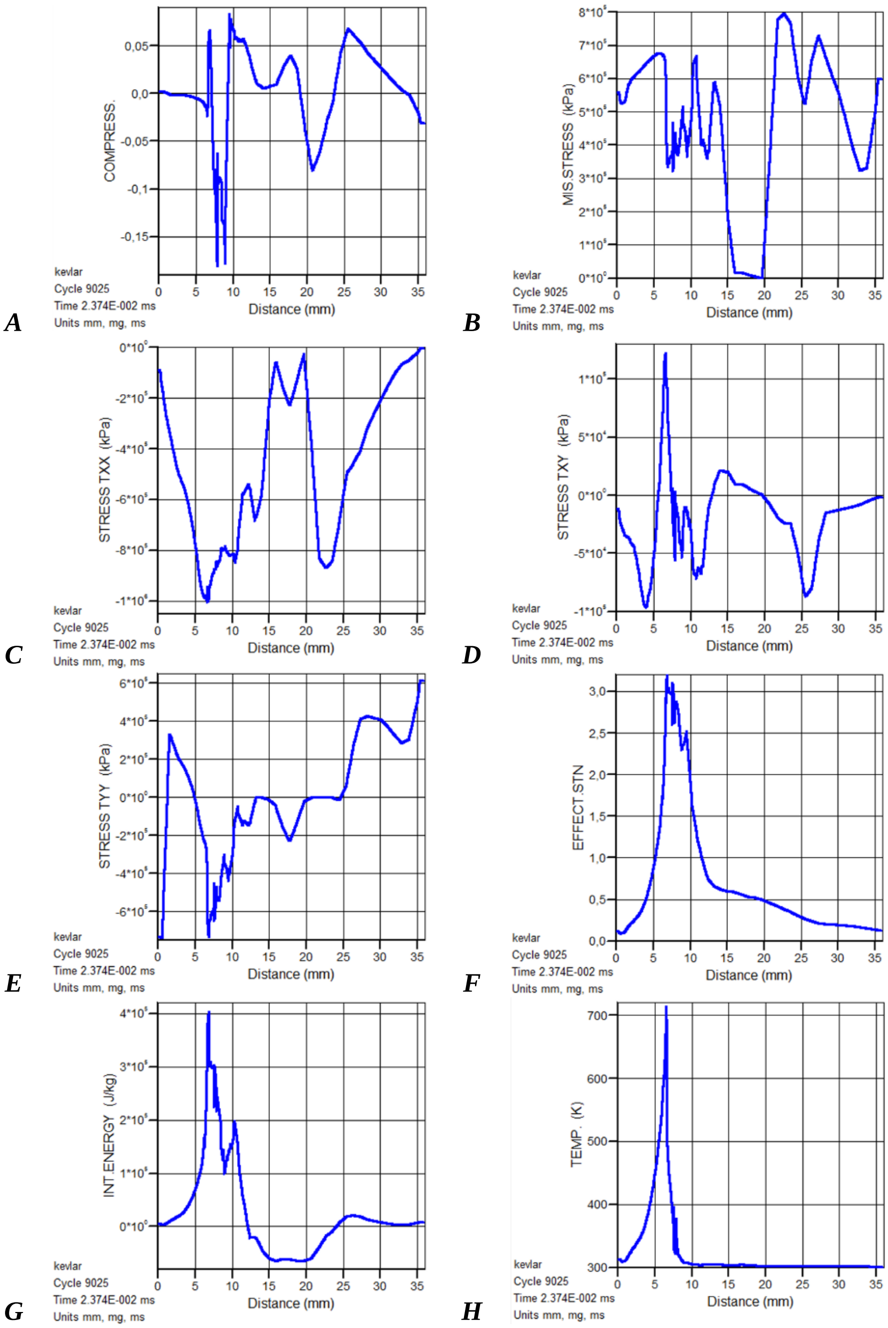

Figure 1 – Simulation results: *A* – compression on the sample thickness; *B* – the von Mises stress on the sample thickness; *C* – stress TXX on the sample thickness; *D* – stress TXY on the sample thickness; *E* – stress TYY on the sample thickness; *F* – effective strain on the sample thickness; *G* – internal energy on the sample thickness; *H* – temperature on the sample thickness.

The impact of the assault rifle bullet on the sample leads to significant deformations at the point of contact. Since the strain of the sample model occurred in a two-dimensional formulation, it is rational to consider the stress of the material in various planes. It can be noted that the stresses along the planes have mostly negative values. This indicates the predominance of compression of the material along the coordinate axis of the bullet flight. A more detailed representation of the compressed state of the sample is displayed on the dependence of the compression of the material on the thickness of the sample. Effective strain of the sample at the point of penetration of the bullet is more than 3, which indicates partial destruction of the material. Significant strains are observed up to the middle of the sample thickness. The internal energy in the thickness of the sample varies in positive and negative values. The negative internal energy calculated in the middle of the sample indicates plastic deformation of the material. The temperature deformation of Kevlar at the impact site increases by more than two times compared to the initial temperature. It is also determined that the equivalent stress of the material is practically absent in the middle of the sample after a direct bullet hit. At the same time, the von Mises stress on the reverse side of the sample is greater than on the side of the bullet impact.

Conclusion

A direct bullet hit leads to nonlinear deformation of Kevlar over the entire thickness of the sample. The predicted values of strain and stresses in various planes and the initial and final temperatures in the contact zone of the bullet and Kevlar were obtained. The nature of the state of the material during a dynamic impact can be traced by the dependence of internal energy on the thickness of the sample: the maximum strain of the bullet and the sample in the contact zone, which turns into plastic deformation in the middle of the sample caused by the release of energy (negative values on the graph) with damping vibrations on the reverse side of the material (deflection of the sample).

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