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WHY BALLISTIC TESTING METHODS OF BODY ARMOR DO NOT GIVE US ACCURATE INFORMATION

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ABSTRACT: In the security sectoralways is attention paid to ensure the best possible protection for their employees.
Manufacturers and especially the users of ballistic protection systems need an adequate answer to the question whether the chosen protection is effective against specific threats. Such evaluation is difficult enough, mainly because ballistic systems of body armors are high technology products and they embody last achievements in different branches of technology and science.
The needed ballistic protection from different threats (bullets, fragments, explosions, stab protection, etc.), makes the only verified and reliable method for effectiveness assessment ballistic test. But are the ballistic tests reliable enough? How they express real situation? What is acceptable risk to assume?
The more often used method for assessment of ballistic protection level is determined by series 0101 NIJ Standards: the body armor, mounted on plasticine block is hitted by different caliber ammo and at one side there hasn't to be penetration, and at other hand the blunt trauma hasn't to exceed 44 mm. These should guarantee body armor ballistic protection rate.
Other "plasticine" based ballistic testing standards have same imperfections, because their origin from 0101 series of NIJ Standards.
This scenario for bullet resistance testing is needed for general reconstruction: the plasticine has a quite different properties in comparison with different areas of human body; the measured value of penetration has only static component – lack of correspondence with real situations, dynamic component (impact wave propagation, character of wave, etc.) isn't included; and last but not least this criteria for high-speed (rifle) bullets never has been compared with human/animal corpses results.
The goal of this paper is to summarize main problems related with this scenario of testing, to characterize in theory the possible consequences after non penetrating impact – mechanical damages, impact wave propagation and other impact phenomena, due to bullet impacts in relation with impact phenomena, and to provide some directions for development of new methods for ballistic testing.

KEY WORDS: ballistic protection, bullet resistance, body armor, ballistic testing standards

1. INTRODUCTION

Modern military forces and civil protection agencies place high priority on providing the best protection possible to their personnel – their most valuable resource.

A ballistic vests are the part of personal armor protection that helps absorb the impact from projectiles and fragments from explosions. Soft vests are made from many layers of woven or laminated fibers and can be capable of protecting the wearer from small-caliber handgun and shotgun projectiles, and small fragments.

For higher level of protection (from rifle rounds and bigger fragments) additional plates can be used with a soft vest. Soft vests are commonly worn by police forces, civilians, security guards, and bodyguards, whereas hard-plate reinforced vests are mainly worn by combat soldiers and police tactical units.

Because the body armors are of vital importance, both users and manufacturers are need for adequate and correct answer to question how far the given ballistic system is effectively to particular threat. However, evaluating the effectiveness of materials and designs for new armour is extremely difficult: although it is easy to see if a given sample has or hasn't actually been perforated by a given ballistic threat under given circumstances, it is generally not evident what injuries the impact of the projectile might have inflicted on a human wearing the armour under test. The design and configuration of ballistic systems are often determined more by user comfort and perception than by their contribution to protection, yet the body armor blunt trauma can be a critical factor in determining injury resulting from an impinging projectile. The capability of the ballistic system to absorb and dissipate energy is an equally important factor in determining how the energy of the impacting threat is transferred to the human body. Conventional body armor evaluation systems using plasticine-based models of the human thorax provide, at best, only an indication of the maximum tolerable body armor back-face deformation. In world practice and particular in Bulgaria is used great number of standardized methods by using of plasticine as backing material all of them based on NIJ standard. This standard (NIJ Standard 0101) has endured five main changes and about ten partial corrections to NIJ Standard 0101.06 [17]. Regardless of these corrections, one could say that, this norm has about thirty years prescription, because the changes of testing procedures are only cosmetics. Unfortunately, performed ballistic test may only access the possibility whether the body armor can stop given ballistic threat and to inconsiderable degree to ensure adequate answer whether body armor blunt trauma is or isn't lethal for human [4]. My practice say, the assessment at these tests is highly inaccurate, because there are great possibility different samples to obtain different results. The tests may call valid if they can give us adequate answer whether the body armor is effective in conditions close to the real battle conditions. Unfortunately the existing standardized methods can't answer this question and even they answer them, the answer is not as precise as needed.

2. PROBLEM STATE

2.1. Basis of plasticine standardized ballistics test

The basic principle of plasticine ballistics test is as follows: the vest is mounted on the plasticine backface fixture and determined number of shots is produced. And the armor system should resist every fair hit and BFS should to be lower than limit (44 mm in NIJ Standard series 0101, 30 mm in Bulgarian testing methodology).

The standards based on this physical principle specifies how to conduct ballistic tests on body armor models under controlled conditions in order to establish the ballistic properties of the samples, which retrospectively are carried on the entire lot.

These types of tests not demand for high-technology laboratory equipment and allow easy collection and data processing – the easiest way for users and manufacturers.

However, to date, they apply a hundred percent for ballistic testing of body armor, because of abovementioned fact, and mostly because of the reluctance of manufacturers of materials and ballistic vests to put things on a scientific basis. Placing the issue on a strict scientific basis would lead to increased costs for research, development and testing at manufacturers. Below the main problems of using of plasticine based standards.

2.1. Differences between real fire situations and ballistic standards

There is a large gap between testing standards and real situation.

Firstly, achieved number of test shots in the norm (and in the other norms), only guaranteed assurance that possibility of tested body armor stop given bullet.

Additionally, most plasticine based standards do not provide multi-hit resistance testing. This makes the gap greater.

A good example in this regard can be taken from CAN/CGSB-179.1-2001 Personal Body Armour National Standard, where it introduced the opportunity to test multi-hit resistance, which makes the setting as close to reality. Moreover, increasing the number of shots increases reliability of the system. But the consecutive shots required by the standard by no means guarantee multi-hit ballistic resistance, because the loading from 3-4 shots at intervals of the order of several hundred ms in burst rate and about 2 s in single shot fire rate, applied on particular area is extremely high in comparison with this that achieved by the same number of shots at intervals of a minute and more. This is because of the ballistic system in the second case has time to restore their ballistic resistance.

Another big problem is the required distance between two bullet shot centers or distance between bullet and the ballistic panel edge is highly whopping and this promotes body armour producers.

The performed tests for 5,56x45 mm and 7,62x51 mm bullets, and results from [2] demonstrate that the distances between bullet shot center are between 2 and 4 cm at distances smaller than 100 m.

The results for 7,62x39 mm AK-47, 5,56x45 mm AR-M1, 7,62x54R PKT and 7,62x51 Arsenal LMG showed confirmation with results in [2] and the distances are between 2,5 and 3,5 cm at 50 m distances for 5,56x45 mm AR-M1, 7,62x54R PKT and 7,62x51 Arsenal LMG and between 3,5 and 4,5 cm at same distance for AK-47.

Another test shows that IIIA type body armor according to NIJ Standard 0101.04 body armor hadn't stopped the next bullet hit in 3,9±0,5 cm distance from previous shot. This distance is about 20% less than required distance from NIJ Standard 0101.04 (fig. 1).

Fig.1. Perforation of IIIA type body armor by next test bullet in distance about 20% closer than required by standard

It's clear that this examined case is particulate and no one could say that all of certified by testing agencies according to NIJ Standard 0101.04 body armors don't stop bullets with distances between their centers less than specified in abovementioned standard. But another thesis is valid too – there is no guarantee that if distance between bullets shot centers is in the gap of 2,5 -4,5 mm (distance in real fire situations), the given body armor resist.

Adding to these problems and the unresolved problem of the influence of aging on the ballistic material quality, the problem is significantly complicated [2].

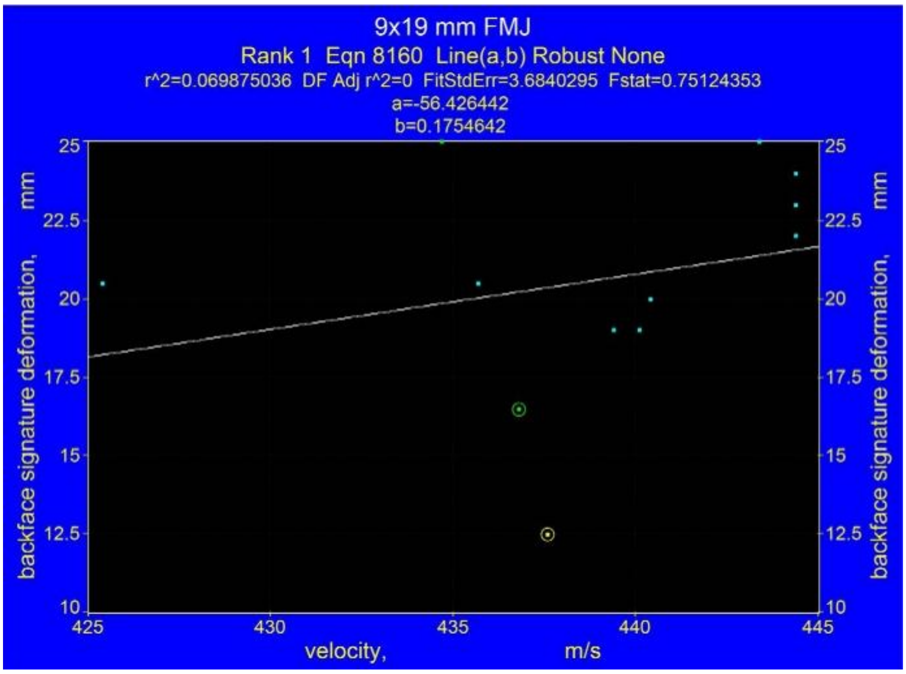
With regard to "bridge the gap" between the ballistic tests and real fire situations, it is necessary to change the pattern of testing.

2.2. Shortcoming of plasticine backing material fixture

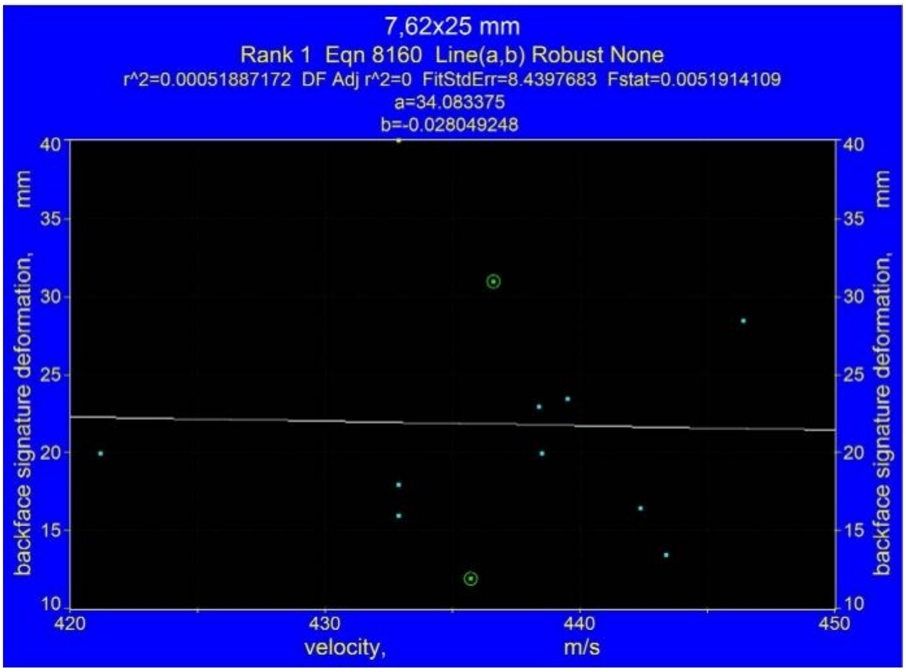
The other disadvantage for standardized ballistic tests for assessment of bulletproof resistance is backing material fixture:

- Plasticine is quite different from human torso;
- Measured value of backface signature penetration (depth of the depression made in the backing material, created by a non-penetrating projectile impact) provides only part of the "static" load, while the "dynamic" components (the waves, history of the deformation process, etc..) can not be registered;
- This criterion of NIJ has never compares favorably correlated with live models (animals) for high-speed bullets.

There are no strong correlation between deformation (backing fixture signature) and achieved bullet velocities (respectively bullet kinetic energy) (Fig.2) and these values haven’t any relation with injuries, especially from rifle bullets.

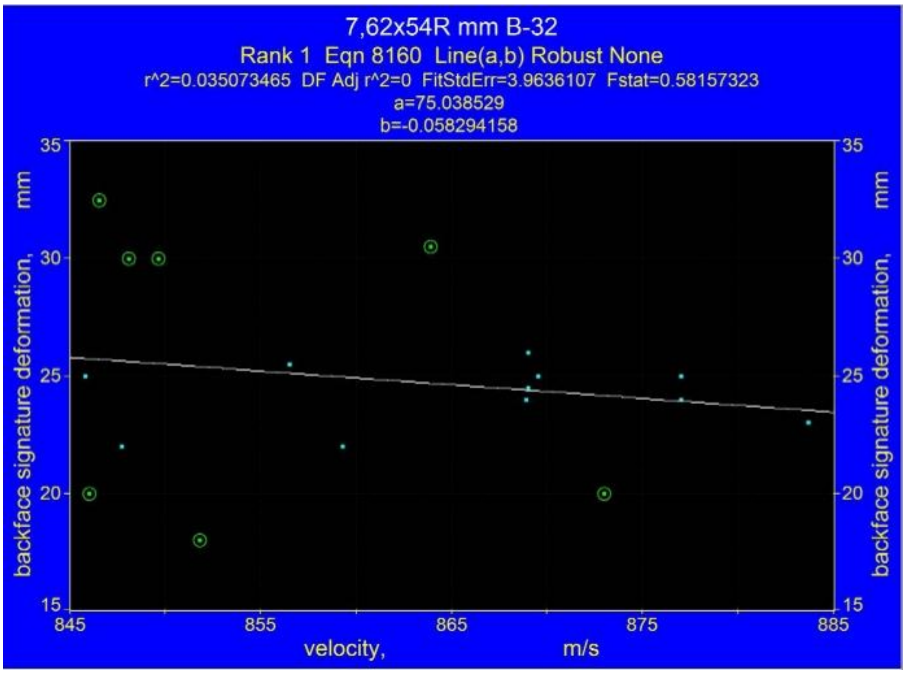


a)



b)

Fig.2 Correlation between deformation (backing fixture signature) and bullet velocities (respectively bullet kinetic energy) for testing ammunition of Bulgarian Army body armor: a) for 9x19 FMJ; b) 7,62x25 mm FMJ (bimetal) and c) 7,62x54R B-32.



c)

Fig.2 (cont.) Correlation between deformation (backing fixture signature) and bullet velocities (respectively bullet kinetic energy) for testing ammunition of Bulgarian Army body armor: a) for 9x19 FMJ; b) 7,62x25 mm FMJ (bimetal) and c)7,62x54R B-32.

As it's shown there're relatively good correlation for 9x19 mm FMJ (this ammunition is testing for NIJ Standard 0101.04), but the one can say that there are no correlation for other two testing ammunitions (they aren't testing ammunitions for NIJ Standard 0101.04).

Because of the backing material has too different qualitative indices in comparison with human body and the measured value from backface signature test show only the static part of the loading and dynamic part (impact wave propagation, deformation history, etc.) is unknown.

3. SOLUTION PHILOSOPHY

A complex solution for improvement of reliability of ballistic testing is needed.

Firstly, the settings of the experiment should to be modified to near maximum to real fire situations – ballistic test should provide real multi-hit resistance with real distance between centers of test bullets and edges of the garment.

For each caliber have to be tested different weapon systems to real bullets dispersion estimate. Additionally, have to be performed different tests for determination how many hits (3, 4 or more) should to resist ballistic system to be multi-hit capable.

On the other hand should to be provided other backface fixture to:

- "copy" structure of human torso;
- capture the "dynamic" components (the waves, history

of the deformation process, etc.) can not be registered.

Reliability of the tests may be increased if instead of such a material is subjected to use more reliable biomechanical models of human torso [1]. Furthermore, this will avoid segregation and ballistic material, which leads to a greater reliability of the data obtained and repeatability for different specimens.

In the context of automobile accidents, powerful numerical tools are available to simulate the impact response of thorax. But in the context of body armor blunt trauma, no equivalent numerical model exists: prediction of thoracic trauma, in particular lung injuries, cardiac hemorrhage, ribs fracture etc. is still very approximate. In comparison with typical automobile impacts, the load is applied very rapidly to the thorax in body armor blunt trauma (BABT) impacts (fig.3).

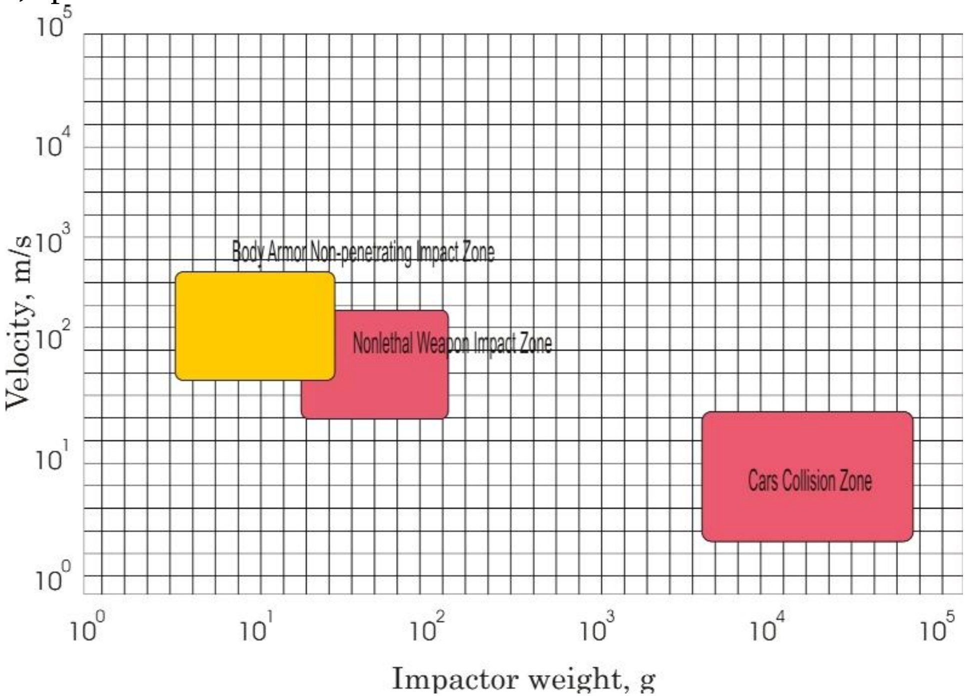


Fig.3. Velocity Mass Diagram for Body Armor Blunt Trauma

At present, the finite element (FE) models of thorax based on a realistic description of the geometry are unable to describe the propagation of the impact energy carried by high frequencies; indeed, the associated waves generated upon impact do not propagate in the FE models because meshes used are too coarse. The required number of elements to describe properly wave propagation is too large. The modeling strategy followed for low-frequency BABT phenomena is close to that developed in the context of automobile accidents. And FE of thorax developed for typical automobile impacts may used for stresses and displacement determination.

But there is a need for other model for high-frequency BABT phenomena. The model shall consider only the main characteristics of the thorax structure implicated in the transmission of the impact energy in the lung through the thoracic wall. Because the loading duration under consideration is very short, the future studies will be limited to the thorax zone under the impact point, and the response is calculated in a very short time window after impact. The assumption is that within a time window of a few hundreds of microseconds, the response of the thoracic wall and the lung is only weakly perturbed by the other parts of the thorax (heart, spine, etc.) and their influence on impact wave propagation will not examined.

Combination of injury criteria development from simulations and more "real" fixture for ballistics testing will enhance reliability of results.

4. SUMMARY

Body armors as a part of personal armor protection are systems that incorporate last achievements of science and technology.

Because of their importance for the preservation of life of users, ballistic tests are the only reliable way to prove their quality.

But most of the ballistics test used methodology origin in NIJ Standard 0101 series.

Regardless, these standards are changed periodically; the physical basis remains the same and the problems with reliability of the ballistic tests remains. The shortcomings of these standards are divided into two groups – differences between the real fire situations and ballistics tests in standards and unsuitability of plasticine based backface fixture.

A complex approach is proposed by author, because of lack of authentic methods and models – to derive injury criteria and to replace backface signature.

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