THE MODEL OF VERTICAL ACCELERATION IMPACT ON BACKBONE OF MEMBER OF THE CREW

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Abstract

This paper presents procedure methodology allowing to evaluate the impact of vertical acceleration (mine detonation under the vehicle) for damages of backbone of the crew member This problem is presented globally with stress on model being the estimator of the backbone damages. Then this study includes standard requirements in this field and discusses the necessary instrumentation and then method for development of model input data is indicated. the vertical impact model is presented on example. The mechanisms allowing to evaluate the level of potential injuries are presented in the final part in this paper.
The range of problems concerning metrology of physical values associating explosion and evaluation of its impact on the human body is very wide. Problems discussed in this paper do not exhaust this field. The research are under way on several topics for their more full recognition. Development of this field will be correctly used, having in mind the aspect and usefulness of such research. The main criterion for evaluation of explosion impact on people protected by armour of the vehicle is the measurement of physical and mechanical values occurring during explosion. The high accelerations and pressures constitute serious danger for health and life of people. Tests are necessary to determine effectiveness of the crew's protection both in vehicles and in other objects.

Keywords: *blast tests, vertical acceleration impact model, anthropomorphic test dummy*

1. Introduction

The main criterion for evaluation of explosion impact on people protected by armour of the vehicle is the measurement of physical and mechanical values occurring during explosion. The high accelerations and pressures associating explosion constitute, due to its nature, serious danger for health and life of people. Tests in which such physical values are recorded are necessary to determine effectiveness of the crew's protection both in vehicles and in other objects.
Procedure presented on Fig. 1 is applied in order to evaluate the potential damages of the human's backbone occurring in result of explosion of the explosive charge.

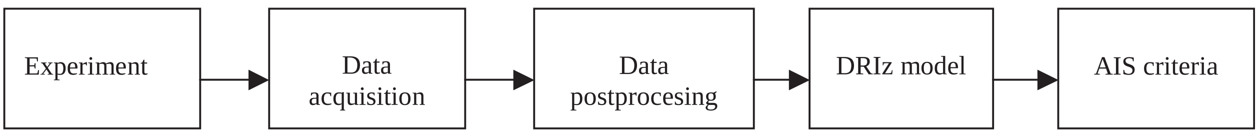

Fig. 1. The example of the influence of the number of thermal shocks on the deformation of the piston sampl

This paper presents method for evaluation of probability of the backbone damages of the member of the vehicle's crew, with the highest stress put on model being its estimator.

2. The data acquiring for needs of this model – problems with measurement of physical values associated to explosion

The problems of measurements associated with explosion is one of the most important topics as regards the modern military solutions [1,2,3]. The main standard document as regards evaluation of effectiveness of protection of the vehicle's crew is STANAG 4569: „Protection Levels For Occupants Of Logistic And Light Armoured Vehicles". This document introduces five levels of bulletproofness, where the highest, the fifth level corresponds with resistance to bullets calibre 25 mm. As regards resistance to explosive charges, STANAG 4569 introduced four levels of protection. One of documents referred by STANAG 4569 is AEP-55: „Procedures For Evaluating The Protection Level of Logistic and Light Armoured Vehicles". AEP-55, Volume 2: „Procedures For Evaluating The Protection Level of Logistic and Light Armoured Vehicles Occupants For Grenade And Blast Mine Threats Level" defines explicitly the metrology instrumentation necessary to examine the vehicle resistance to explosions. It includes:

- at least one ATD anthropomorphic test device, type Hybrid III 50 centiles,
- at least two pressure measurement transducers,
- sensors (displacement, force, acceleration) located on seats and floor, and in the structure centres of the object,
- cameras, in that one fast, min 1000 frames per second.

The ATD structure is subject to the separate regulations. These units were constructed for the cars' frontal crash tests [3,4]. They are so constructed to reconstruct, as best as possible, construction of the human organism. The skull and skull cap are one piece cast aluminium parts with removable vinyl skins. The neck is a segmented rubber and aluminium construction with a centre cable. It accurately simulates the human dynamic moment/rotation flexion and extension response. The rib cage is represented by six high strength steel ribs with polymer based damping material to simulate human chest force-deflection characteristics. Each rib unit comprises left and right anatomical ribs in one continuous part open at the sternum and anchored to the back of the thoracic spine. A sternum assembly connects to the front of the ribs and includes a slider for the chest deflection rotary potentiometer. The angle between the neck and upper torso is determined by the construction of the neck bracket which can incorporate a six-axis neck transducer. A two-piece aluminium clavicle and clavicle link assemblies have cast integral scapulae to interface with shoulder belts. A curved cylindrical rubber lumbar spine mounts provides human-like slouch of a seated person and mounts to the pelvis through an optional three axis lumbar load cell. The pelvis is a vinyl skin/urethane foam moulded over an aluminium casting in the seated position. The ball-jointed femur attachments carry bump stops to reproduce the human leg to hip moment/rotation characteristics. The femur, tibia and ankle can be instrumented to predict bone fracture and the knee can evaluate tibia to femur ligament injury. The foot and ankle simulates heel compression and ankle range of motion.

The acquiring of acceleration in the lower part of the pelvis during experiment is necessary for model of vertical acceleration impact on the human backbone. The location of measuring transducer and the standard reference system are presented on Fig. 2. The course of acceleration a(t) must meet relevant conditions, in particular these concerning parameters of recording[5,6]. As the range of input signal values is unpredictable it is necessary to assume high values of signals to protect expensive measuring transducers against damages. However, in case of low value measured signal (small relation of effective signal to measuring range of transducer) it is desirable to record it with the specified resolution, guaranteeing further processing. It requires to apply at least 12-bit resolution. The sampling frequency at least 10 kHz is required, due to the nature of this phenomenon. The sampling frequency on 200 kHz level and more is recommended to provide as small level of errors as possible. The anti-aliasing filters will be incorporated into data acquiring system in order to eliminate aliasing effect and risk of errors resulting from resonance of transducers. It is important from the point of view of metrology correctness that the anti-aliasing filters will be provided with cut off frequency at least 10 times lower than the sampling frequency.

The data processing after recording is restricted to signal zeroing and filtering by numerical procedures. Zeroing is aimed to find the reference level for the measured values. The zero level may shift for various reasons so the signal average value directly prior experiment is adopted as zero level[6,7].

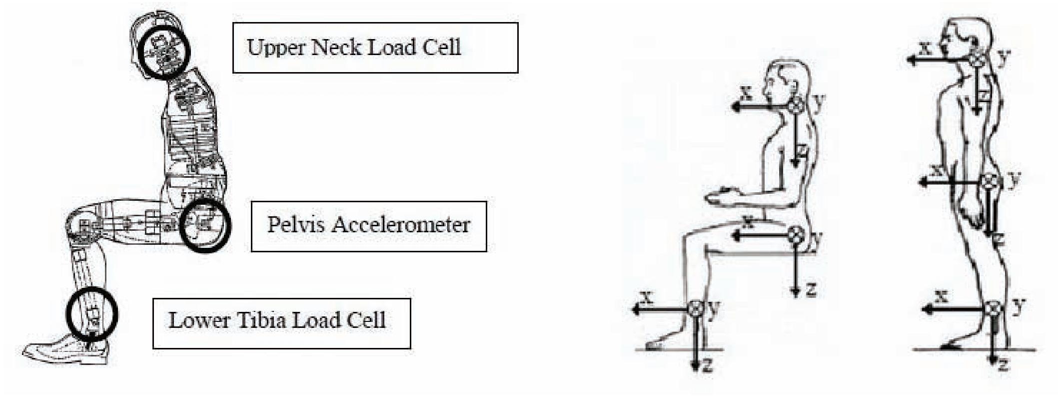

Fig. 2. The location of measuring transducer and the standard reference system

The two courses are presented below. Fig. 3. presents the recorded course of a(t), Fig. 4. presents the course of a(t) after LPF, without the compensated zero drift.

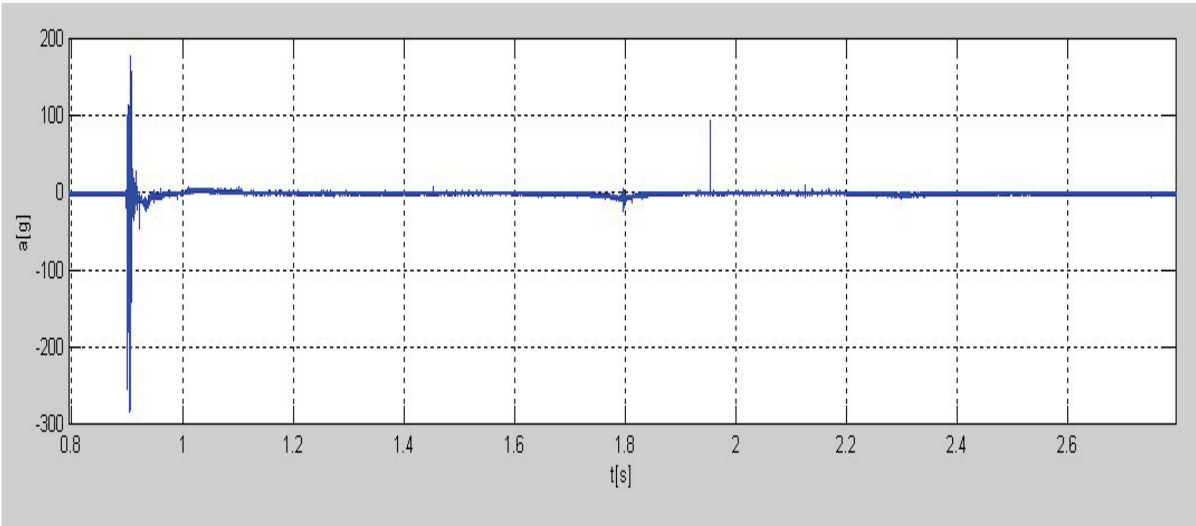

Fig. 3. The recorded course of a(t)

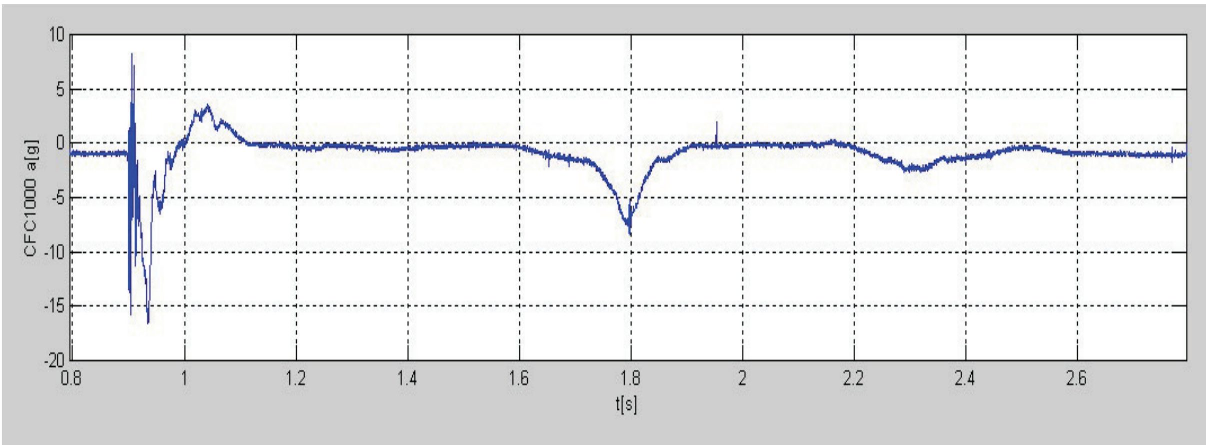

Fig. 4. The course of a(t) after LPF, without the compensated zero drift

Filtering must leave the frequency band relevant for the object. It is connected with weight and natural frequency of the given object [2]. Generally, the filter classes are selected in the following way:

– safety belts 60,
– forces and moments in limbs 600,
– forces and moments in loin backbone 600,
– moments in neck backbone 600,
– forces in neck backbone 1000,
– accelerations in head and shanks 1000.

The phase less filters are used for filtering. The low-pass filter, second layer (40dB/decade), Butterworth filter and FFT based filters are used. Fig. 5. presents the course of a(t) filtered by Butterworth filter not introducing the phase shifts.

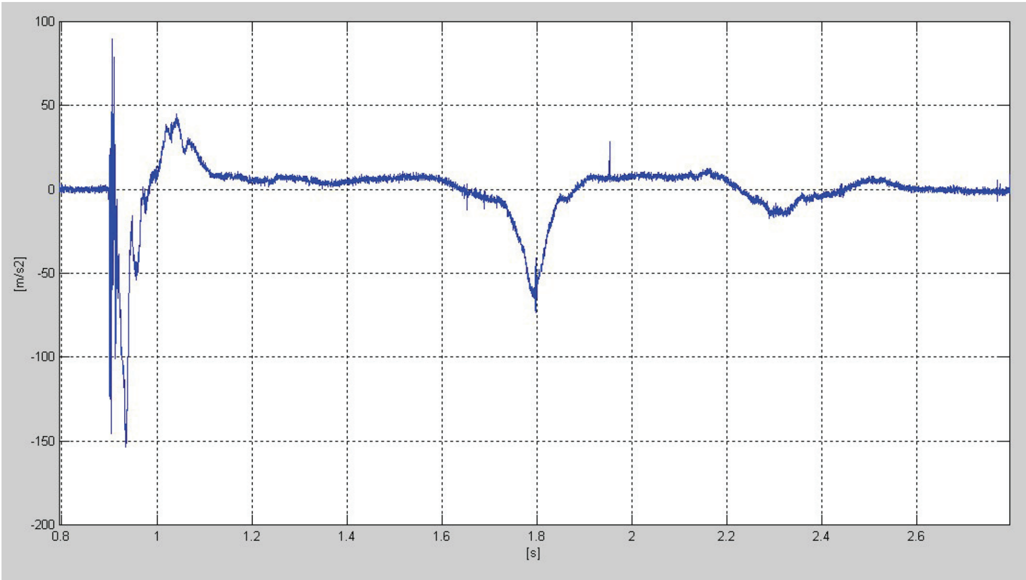

Fig. 5. The course of a(t) subject to phase less filtering by Butterworth filter

The prepared in such a way a(t) signal serves as the input variable in model. It will serve to assess probability of damages in the human backbone in result of the vertical acceleration.

3. The backbone model and Dynamic Response Index for axial direction – DRIz

The simplified backbone model was developed to determine DRIz. This model includes weight subject to acceleration through the parallel connection of the elastic element with the suppressing element.

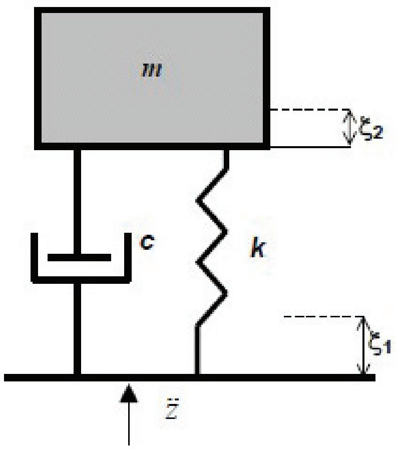

Fig. 6. Backbone model

The movement equation for this model:

$$z(t) = \ddot{\delta} + 2 \cdot \varsigma \cdot \omega_n \cdot \dot{\delta} + \omega_n^{\ 2} \cdot \delta \,, \qquad (1)$$

where $z(t)$ is the acceleration i the vertical direction (m/s^2),

$\delta = \xi_1 - \xi_2$ - is the deflection,

$\zeta = \dfrac{c}{2 \cdot m \cdot \omega_n}$ - is the damping coefficient (0.224),

$\omega_n = \sqrt{\dfrac{k}{m}}$ - is the natural frequency (52.9 rad/s).

DRIz index is calculated on the base of equation for the maximum compression:

$$DRIz = \frac{\omega_n^{\ 2} \cdot \delta_{\max}}{g} \,. \qquad (2)$$

The numerical modelling is one of the method to solve the presented above model. The author applies for this purpose Matlab package, and model is implemented in Simulink environment. The solution of model allows to present graphically the compression value and its derivatives. Figures 7, 8, 9 present successively δ, dδ/dt, d2δ/dt2.

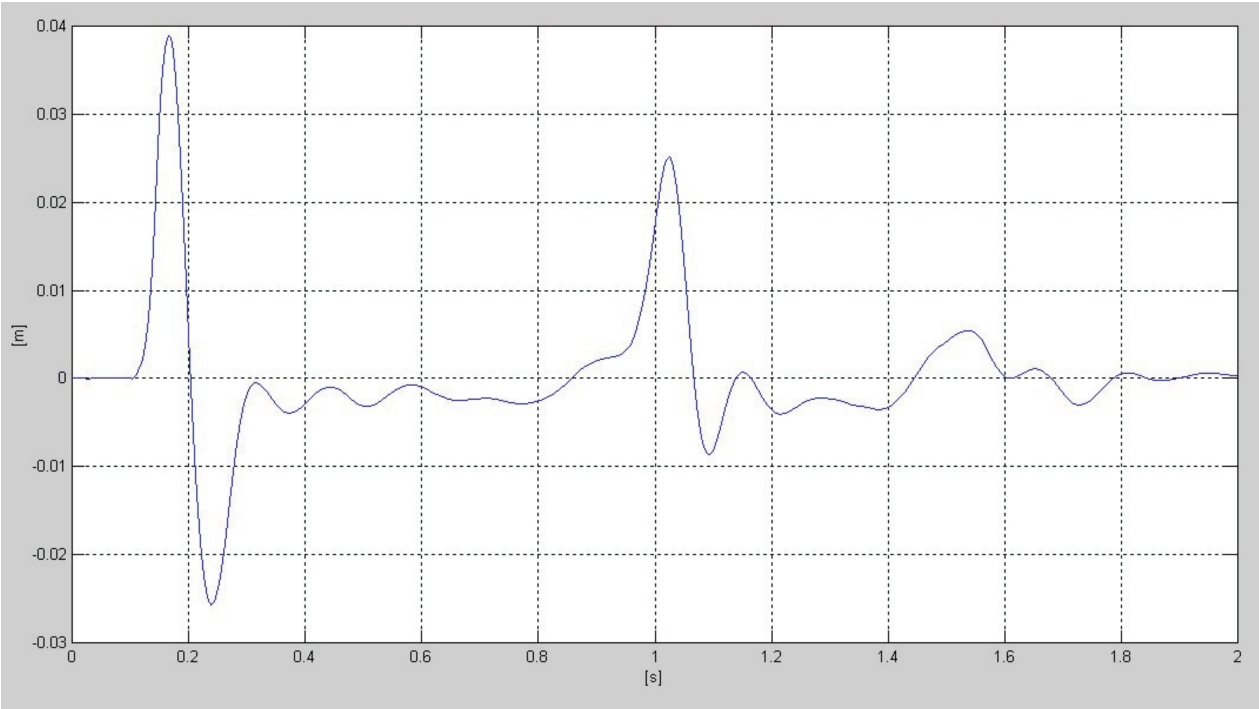

Fig. 7. Backbone compression δ(t)

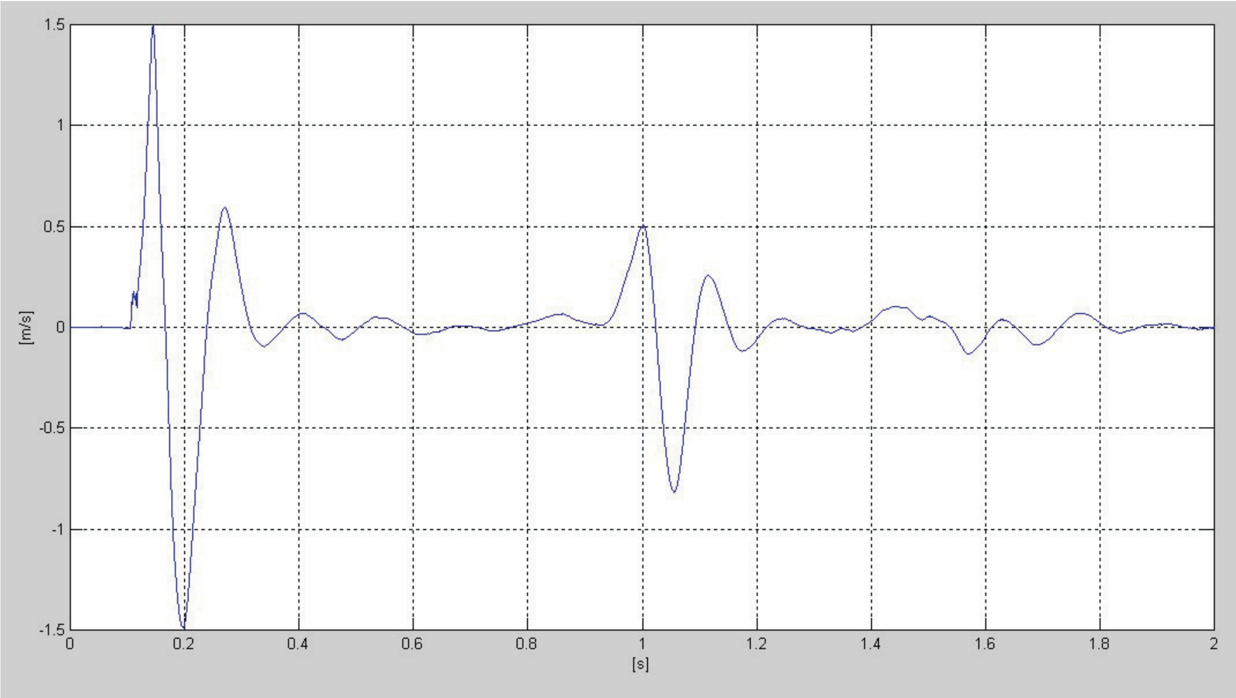

Fig 8. Speed of backbone compression $d\delta/dt(t)$

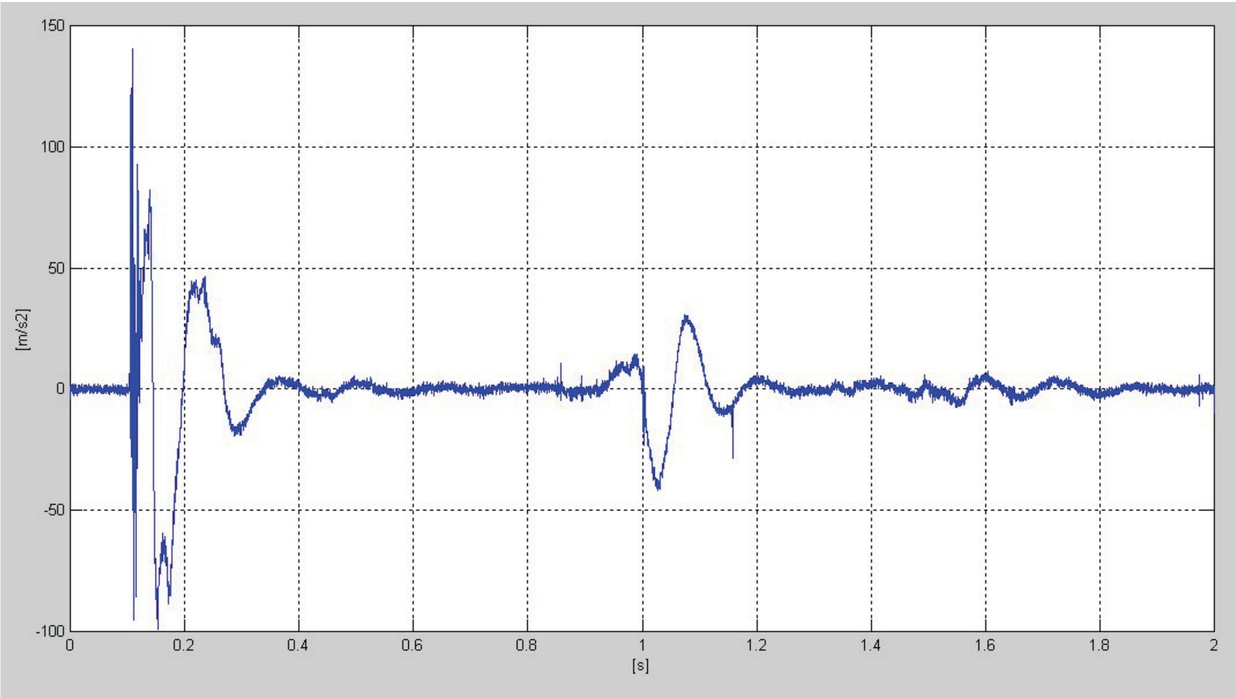

Fig. 9. Model acceleration inside backbone structures $d2\delta/dt2(t)$

DRIz index is used to assess extension of backbone damages. DRIz index is connected with AIS scale (Abbreviated Injury Scale are ranked on a scale of 1 to 6, with 1 being minor, 5 severe and 6 an unsurvivable injury). The limiting DRI value according to NATO STANAG 4569 is 17.7 with a 10% chance of serious injury (AIS 2+). This corresponds to a maximum spinal compression of about 62 mm. Fig. 10 presents curve linking DRIz index value with level of backbone damage probability.

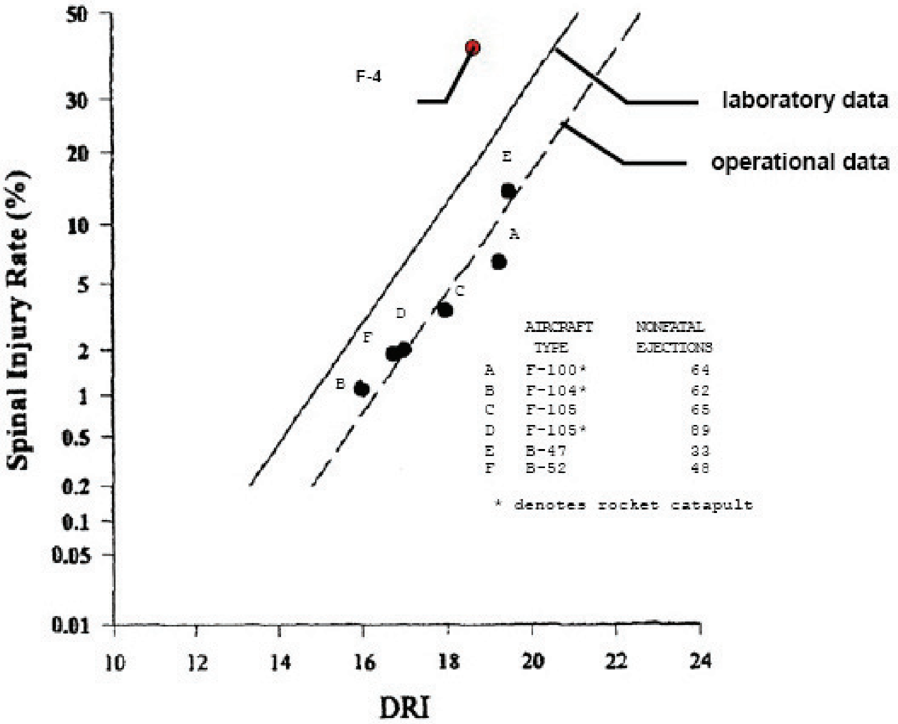

Fig. 10. DRIz index value with level of backbone damage probability

4. Summary

In conclusion, the Dynamic Response Index (DRIz) model is at this point the best available model for thoraco-lumbar spine injury assessment. The DRIz is to be calculated with the pelvis ATD vertical acceleration. Based on discussions on the two risk curves available in literature (see Figure 10).

The range of problems concerning metrology of physical values associating explosion and evaluation of its impact on the human body is very wide. Problems discussed in this paper do not exhaust this field. The research are under way on several topics for their more full recognition. We will hope that development of this field will be correctly used, having in mind the aspect and usefulness of such research.

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