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THE ASSESSMENT OF THE INFLUENCE OF SELECTED PASSIVE SAFETY SYSTEMS ON THE LEVEL OF DYNAMIC LOADS OF SOLDIERS DURING COLLISION

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Abstract

The work describes chosen problem connected with using of armoured personnel carriers (APC) in the frame of military operations. The soldiers inside the APC are exposed to dynamic loads and shock which are, among other things, an effect of collision with other vehicle or terrain obstacles. In military vehicles, which design is based on a rigid frame or integral body, there is no technical solution to mitigate the effects of a crash. The only applicable means of protection against the effects of collisions are lap belts and helmet designed to protect the head. Preliminary research shows that this kind of equipment is not sufficient. In the work an assessment of the influence of chosen solutions of safety belts and helmets on dynamic loads of carrier's crew during collision with a rigid obstacle are presented. In simulation researches the HYBRID III dummies models have been used and calculations were carried out in LS-DYNA system. The work shows the numeric test results. Behaviour of the dummies during the impact on both the driver and crew member were presented. To assess a risk of injury standard indicators of crash test were used, including: maximum value of the head acceleration and the maximum values of the forces and moments in the neck. The distributions of these parameters were presented. The assessment of applied passive safety systems was made from the point of view of treat to soldiers inside a carrier.

Keywords: *armoured personnel carrier, impact, passive safety, dummy, FE analysis*

1. Introduction

In contrast to advanced passive safety systems used in car, those found in military vehicles, especially in fighting vehicles, usually are characterised by smaller degree of complex. This is not caused by a lack of desire to protect soldiers, but only different terms of vehicle use, including in combat actions. The main type of vehicle used for conveyance of troops and their support in combat operations are armoured personnel carrier (APC). In the course of the implementation of the tasks, particularly in the field, military vehicles usually move with lower speeds than passenger cars, although during collisions with other vehicles or necessity of ramming terrain obstacles larger values of acceleration are generated. Largely, this is result of rigid body of carrier and a lack of crumple zone, which might absorb a large part of the impact energy. In military vehicles, which design is based on a rigid frame or integral body, there is no technical solution to mitigate the effects of a crash.

In combat operations, it is essential to provide possibility of a quick exit of soldiers from the vehicle, but too extensive safety belt systems may make it difficult. Account should also be taken of the fact that the soldiers are wearing equipment weighing about 30 kg, which in an additional way impedes to take a seat in comfortable position and to fasten a belt in a proper way. In the vast majority of used APC at most lap belts are applied, and systems using four point belts are mostly used in combination with special mine protected seating. Preliminary researches show that lap belts are not sufficient in all situations [2, 7].

The aim of the work was to determine the influence of the helmet and safety belt systems on the level of dynamic loads acting on soldiers during a frontal crash of the vehicle with a rigid barrier at low speed collision.

2. Test object model

The simulation tests were conducted on the basis of APC Rosomak model. In order to assess the exposure of the crew members on dynamic load, it was necessary to complete that model of driver and troops seats with the dummies. To the tests a Hybrid III 50th male dummy model in a seated position were used, which is a good representation of the average population of men. Applied model was developed and verified by the Livermore Software Technology Corporation [4, 5], a manufacturer of software LS-DYNA. The applied dummies are equipped with sensors that allow specifying the acceleration and forces in parts of the body, which are important, form the human life threat point of view. This type of dummy is commonly used in numerical researches of cars crash test, however, for military applications it is mainly used to assess occupant injury caused by mine blasts [1, 6, 8].

The dummy placed in the driving compartment was placed on an integrated driver seat of APC Rosomak. Dummies in landing troops compartment were located perpendicular to the direction of vehicle movement. Their feet were based on the opposite seat footrests. In the model was included the possibility of contact between individual dummies themselves as well as with elements of the vehicle's equipment. Location of the dummies inside the carrier is presented in Fig. 1.

a) *b)*

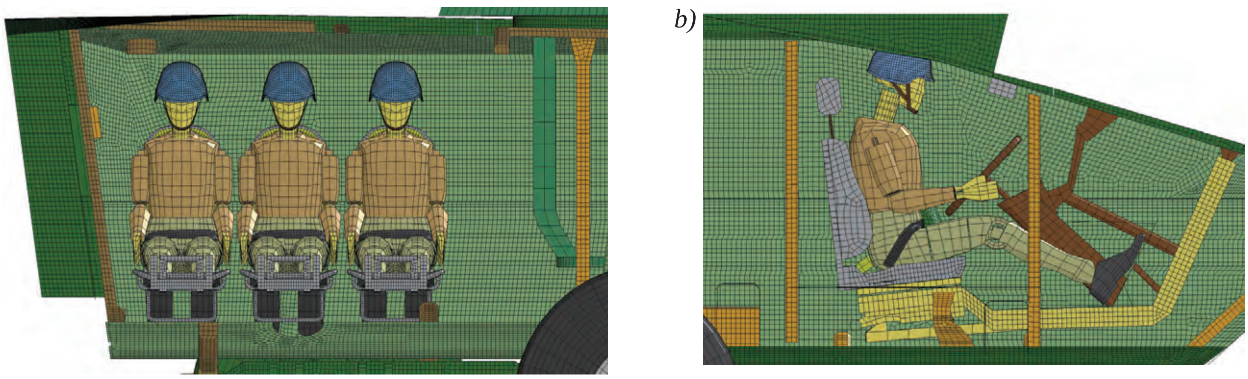

Fig. 1. The location of dummies inside a carrier: troops (a), driver (a)

For dummies placed in driving and landing troops, compartment calculations were carried out for three cases:

a) case I – dummies were fastened using the standard lap belt,
b) case II – dummies were fastened using four-point seat belt,
c) case III – like first case plus head helmet.

Calculations were conducted for the two initial velocities – 11 and 22 km/h. The run of vehicle acceleration (Fig. 2) for first velocity is result of experimental researches of crash of armoured personnel carrier with a rigid obstacle.

In order to assess the results of described above cases of calculations, during numerical simulation displacements, velocities and accelerations of dummies were computed as well as the following criterion [3]:

a) HIC (Head Injury Criterion),
b) the maximum value of the resultant acceleration of the head a_h [g],
c) the maximum value of the tension F_z and shear F_x force of dummy neck,
d) the maximum value of bending moment M_y of dummy neck.

In all cases movements of the dummies was analysed and evaluation criterions were computed.

The calculations were carried out in the LS-DYNA system.

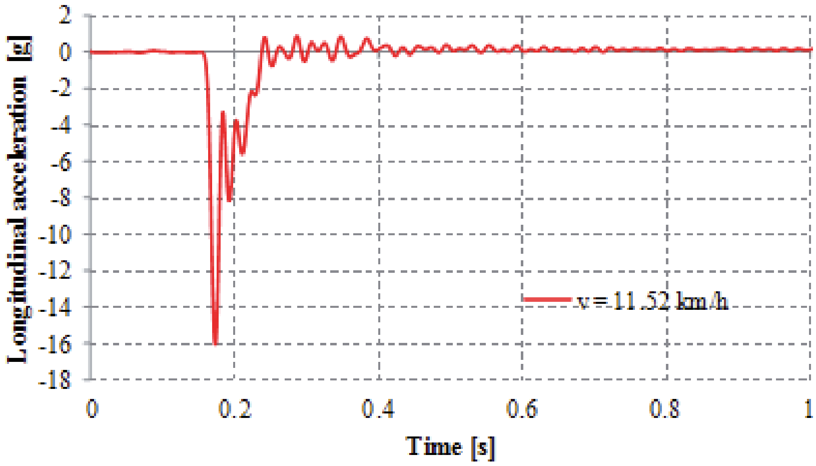

Fig. 2. Acceleration of vehicle – v = 11 km/h

3. Numerical tests results

In all cases, the extortions to the model were course of carrier's body acceleration. During a collision with rigid barrier, the carrier was stopped and next was slightly rebounded from obstacles.

Phases of motion of the dummy located in the driver's compartment are presented in Fig. 3. The results were calculated for the second case to 11 km/h initial velocity.

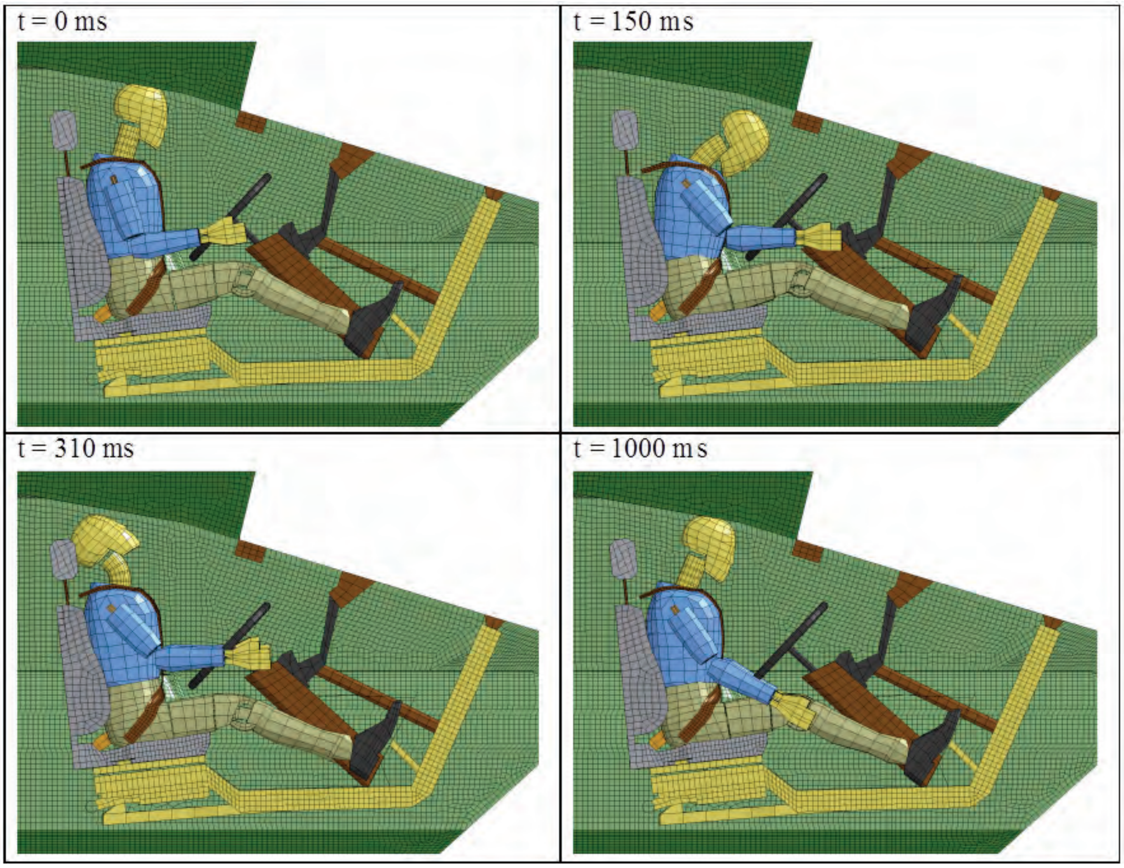

Fig. 3. Phases of motion of the dummy located in the driver's compartment (case II, v = 11 km/h)

Due to the use of a four-point seat belt, motion of the whole body is significantly limited. Only motion of the head and shoulders is visible. After 150 ms, the body was stopped and a maximum neck bending was occurred. After 310 ms, the body was bended backwards and next was stopped on the backrest of the seat, while the head slightly leant backwards.

Depending on the method of dummy fixing, its different behaviour is observed. To case I, due to a lack of shoulder belt, the torso of the dummy is not held. As a result, during collision, a dummy head hit the housing of the ventilation system. In this moment a severe deflection of the head to the back has been observed, which results in the generation of large forces in the upper neck. For higher velocity of collision, after partial destruction of ventilation housing, the further movement of the dummy occurs and finally his body and head hit the steering wheel.

Behaviour of the dummy on the crew member's seat to case III is showed in Fig. 4. Due to the lateral position relative to the direction of movement, after impact, the movement of the dummy on the left occurs. The lap belt causes that the lumbar are held whereas the dummy torso rotate and bends to the front simultaneously. Helmet weight causes increased leaning of the neck in relation to the case without the helmet. For higher velocity, hitting soldiers on themselves is observed as well as their striking the seats of adjacent soldiers.

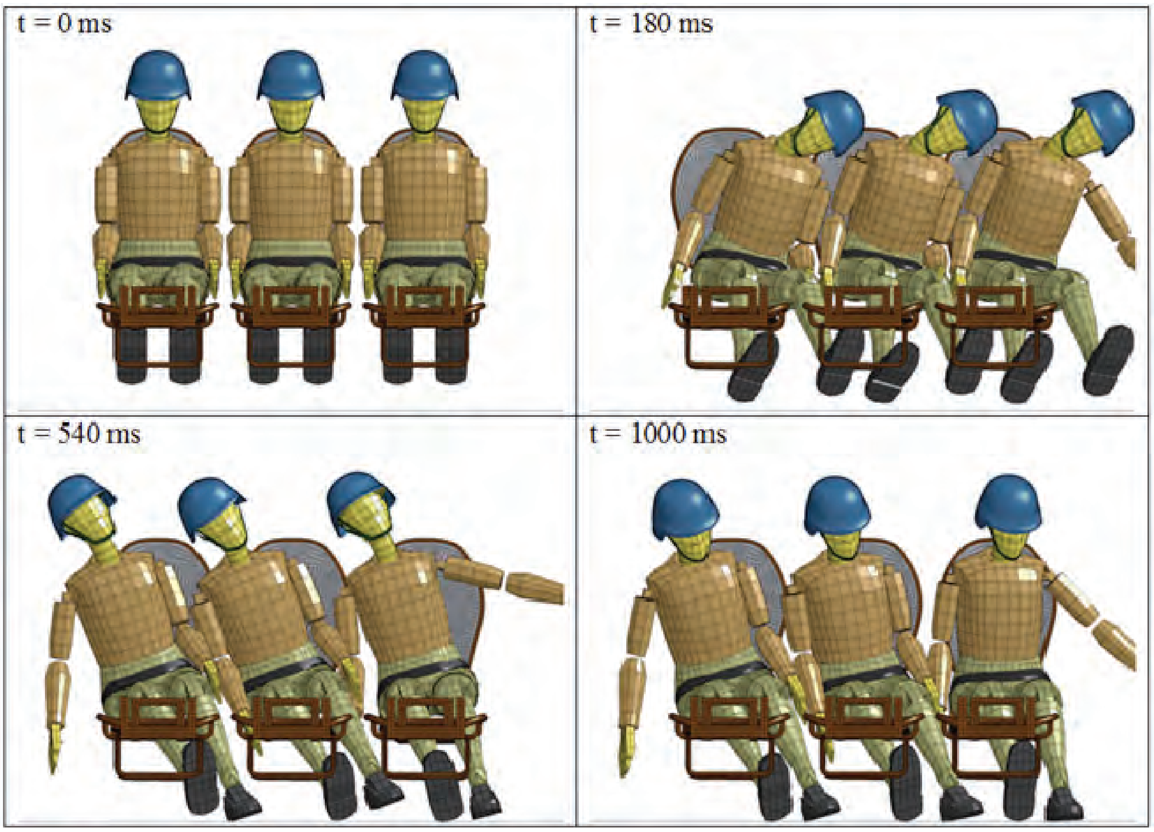

Fig. 4. Phases of motion of the dummy located in the landing troop compartment (case III, v = 11 km/h)

Table 1 summarizes the results obtained for the considered cases. In each column were indicated the maximum values of evaluation indicators, separately for driving and landing troop compartments. It should be noted that, in the event of a driving compartment all evaluation indicators have maximum values for dummy wearing a helmet and fastened by lap belt. From this point of view, this is worst case. Mainly, this is due to the fact, that the helmet hit the edge of the manhole. Without the helmet, the dummy's head struck only in the housing of ventilation. In the case of the landing troop compartment results are no longer so clear. Maximum values were obtained for case II or III. For the dummy without the helmet, fastened by lap belt, the possibility of large movements reduced the value of the dynamic loads.

Distribution of upper neck tension forces for the analysed cases is presented in Fig. 5. An influence of impact velocity on the achieved the maximum values are visible on it. The greatest value of the tensile forces occurred in the case III. The additional weight of the helmet increased the value of the inertia forces and as a result, the forces acting on the neck. In driver's compartment

Tab. 1. Summary of results for test dummies

	Velocity [km/h]	A driving compartment			A landing troop compartment		
		case I	case II	case III	case I	case II	case III
Resultant acc., a_h [g]	11	31.8	52.9	139.35	13.5	18.1	12.0
	22	118.2	58.6	395.5	38.3	40.1	43.8
HIC	11	55.4	8.9	912.1	16.0	28.7	8.9
	22	352.1	64.7	1428.0	105.7	152.2	205.6
Tension force, F_z [N]	11	798.7	388.4	2167.1	508.4	659.7	873.3
	22	1234.7	682.0	3835.5	1527.7	1619.3	2142.8
Shear force, F_x [N]	11	315.2	408.1	961.7	405.2	506.4	481.4
	22	985.6	557.0	2339.8	810.3	843.3	741.1
Bending moment, M_y [Nm]	11	37.4	30.1	44.7	19.9	22.7	29.5
	22	95.2	38.0	101.8	24.9	44.3	26.4

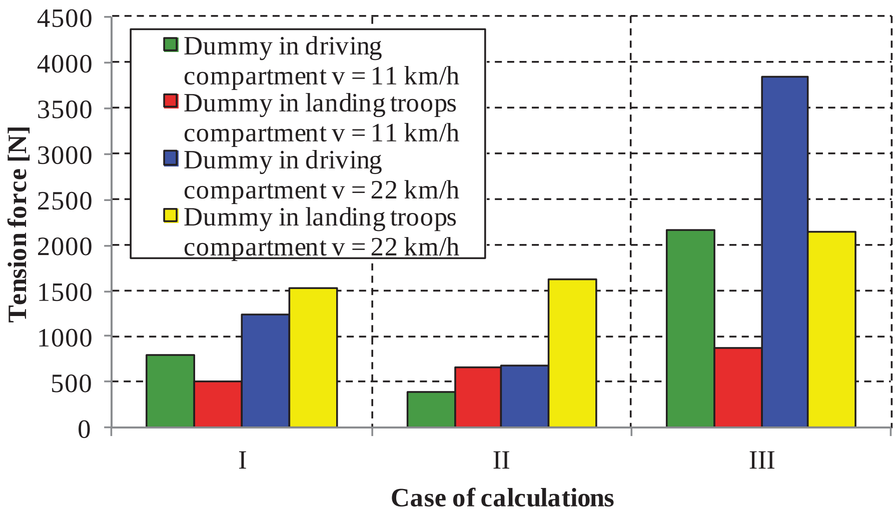

Fig. 5. The distribution of upper neck tension forces

large volume of helmet increases the likelihood of contact with elements of the vehicle. Thus, it also leads to an increase of forces in the neck. Taking into account the capping limit 3.3 kN specified to in [3], can be said, that it has been exceeded for case III for dummy in driving compartment.

The maximum values of upper neck shear forces is showed in Fig. 6. The distribution is similar to that described above. Here also the least preferred is case III. For the case, III for dummy in driving compartment the capping limit 1.9 kN [3] has been exceeded.

Apart from the value of the maximum forces, important from the point of view of the soldiers' exposure to injuries, it is also the value of the bending moment. Depending on the type of seat belt used, the courses of the neck bending moment differ. The courses of neck bending moments of dummies fastened with lap belt and four-point safety belt during the impact with initial velocity 11 km/h are showed in Fig. 7. In the case of a lap belt, significantly greater displacement of body occurred. As a result, the head impacted housing of ventilation system, thereby was leading to a strong neck bending towards the back (1 point on a chart). During the return, the body was stopped on seatback; the head was hitting the seat headrest and was leant back again (point 2). In the case of four-point seat belt the dummy body movement of was stopped and decelerated head was leant forward (point 3). Thus, extreme values occurred in those cases in two different phases of dummy's motion.

On the basis of course of bending moments, maximum values are specified. They are presented in Fig. 8. On the basis of obtained results, it can be concluded that restricting movements of dummy in landing troop compartment by four-point seat belt fastening leads to a little increase the values of neck bending moments. Thus, it is advantageous for dummy in driving compartment. This method

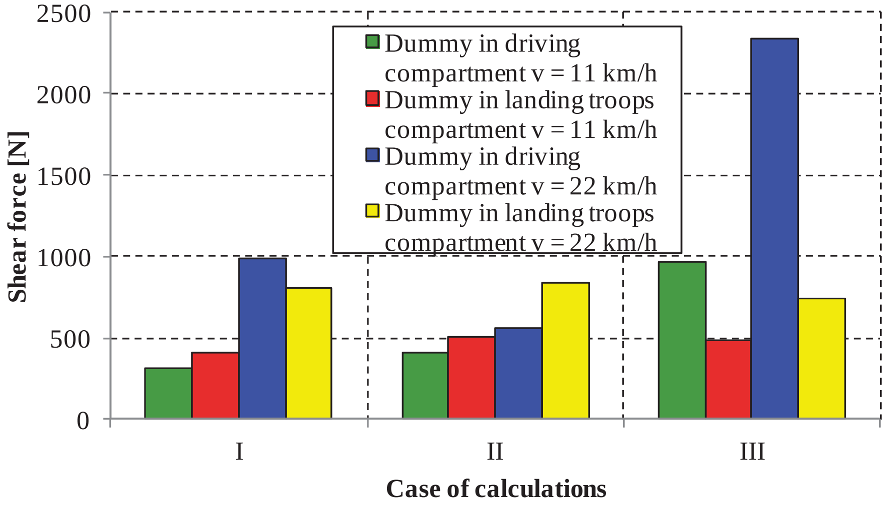

Fig. 6. The distribution of upper neck shear forces

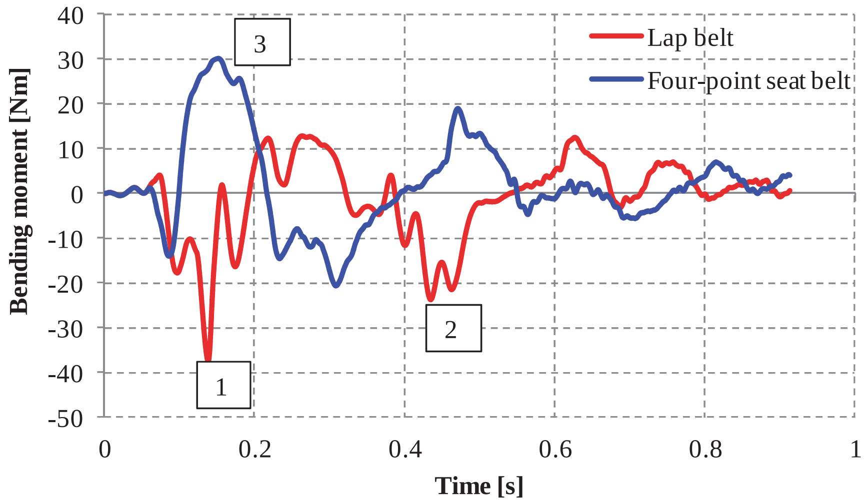

Fig. 7. The course of the neck bending moment (v = 11 km/h, dummy in driver's compartment)

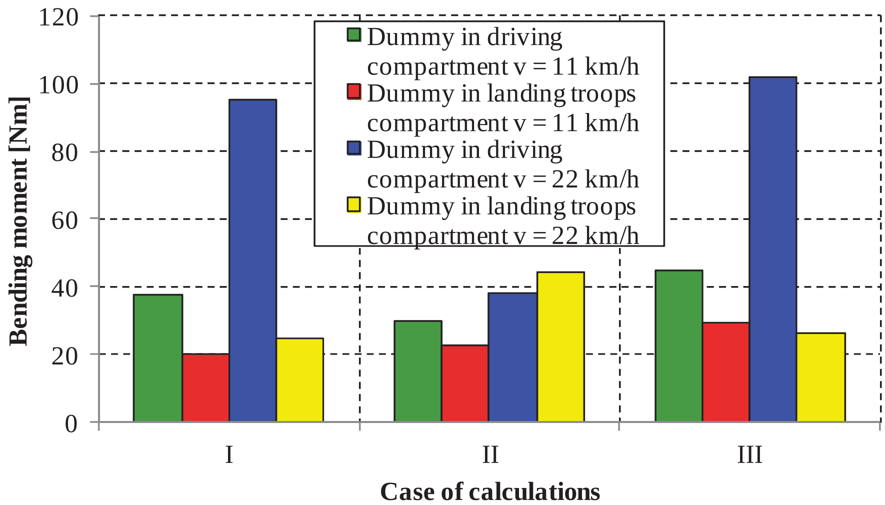

Fig. 8. The distribution of neck bending moment

of fastening protects a head from striking the hard elements of vehicle equipment. For driver, a capping limit 57 Nm has been exceeded for cases I and III. Overrunning this limit means a high probability of significant risk of injury.

3. Conclusion

The results presented in this paper make a part of the experimental and simulation research carried out in order to define a level of threat for the armoured carrier crew during collision with various objects. On the basis of the obtained results it can be concluded that the best solution for driver of armoured personnel carrier is four-point safety belts. Due to highly restricted space inside a carrier, reduction of soldiers' body movements is essential. Insufficient fastening, during a collision, leading to significant movements of the body of the driver. It causes contact with the elements of vehicle equipment. However, higher dummy displacement in the landing troop compartment reduced the values of forces and accelerations.

Received results confirmed the significant influence of vehicle velocity on the level of dynamic loads acting on the crew. For higher velocity, the capping limits of forces and moments in upper neck were exceeded for dummy in driving compartment. It means significant risk of soldiers' injury.

In the framework, the analysis was limited only to two methods of dummies fastening. The influence of helmet was considered as well. The additional weight of the helmet increased the value of the inertia forces and as a result, the forces acting on the neck. On the other hand it protects the head from injury. It should be pointed, that soldiers in the vehicle have individual equipment, which possess significant mass. It may include among others bulletproof jacket and weapons. It can substantially affect the loads acting on the head. For this reason, it seems advisable to widen the analysis of the above-mentioned aspects.

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