Development of Stab and Impact Resistance Tester for Body Protector

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Abstract

To tackle unruly crowds, the police and paramilitary forces use body protectors to protect them from injuries due to attacks of stone pelting, lathi, and stabbing. Therefore, it is an essential requirement to check the quality of body protectors for stab and impact resistance properties. To get first-hand information regarding actual requirements of quality of body protectors, in the first part of the study, a survey was conducted among the 200 soldiers of *Rapid Action Forces. One of the important findings of the survey was that 41% of soldiers informed that the present body protector is not suitable to protect them from sharp objects, stones, lathi, bottles, and petrol bombs. As there is no instrument available to test stab and impact properties of body protectors, they are not testing these qualities scientifically. In the second part of the study, an indigenous stab and impact resistance tester has been developed. The instrument is capable to test stab and impact properties at different angles of incidences. Body protector samples are tested on the developed tester for stab and impact properties and results of stab resistance at 25J and 65J strike energy levels with an impact angle of incidence of 0^o on the test panel are compared and verified with the same lot of samples tested in international laboratories.*

Keywords: *Body protector, impact resistance, knife, plasticine, stab resistance*

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1. Introduction

Paramilitary forces and state police have the duty to control and regulate the crowds in internal areas of the country. The violent crowd converts the protest and agitations into a fierce battlefield with flying sharp projectiles and hurling stones at the security forces. The risk of a protest turning violent has increased in recent times, this has resulted in injuring and killing of security personnel. Earlier studies [1-6] on the impact of sharp tips and sharp-edged weapons on the human body have shown that most of the injuries were found on the chest and abdomen. These studies emphasize the need of providing suitable protective gadgets to defense and police personnel which can save chest, abdomen, and pelvis areas. Studies have also been carried out [7–15] to use various types of fabric and structures to develop stab, cut, and impact resistance ensembles. To protect these soldiers from attack by rioters using stone, projectiles, sticks, Molotov cocktails, knives, or any other type of weapons they are provided, body protector. A full body protector includes Helmet and body protector (antiriot suit). A body protector is a protective suit comprising eight parts. An upper bodysuit that guards the neck, shoulders, chest area, and groin is called a chest protector. Each hand is covered by an upper arm, forearm, elbow pad, and elbow guard. The lower part is protected by a thigh guard and shin guard with the help of fasteners. These parts are detachable from the complete suit. Each part of the full-body protector comprises rigid hard material for the outer layer for protecting the limbs of a wearer against sharp objects and projectiles and soft paddings to protect them from any impacts.

Presently the performance of the body protector in India is evaluated by the defense personnel themselves by throwing stones and bricks from 45 yards distance, or by attacking by lathi (plate) to stimulate the riot situations. These results vary from person to person, as the force applied by an individual of throwing a stone or attacking by lathi is vary. Due to this, there are always chances of a dispute between buyer and seller.

The most common standard for testing stab and impact properties of body protectors are NIJ standard-0115.00 (only for stab resistance) [16] and VPAM KDIW 2004 standards. Out of these VPAM KDIW 2004 Edition, 2011 [17] is now added in the MHA specs no L-VII-08/2015-19-Prov DA 5 (Part 1) dated 27/09/2019 [18] for body protector. In India, there is no instrument available to test the stab and impact resistance characteristics of the body protector as per this standard. For testing these properties, samples need to send abroad. This process is very costly and required a long duration to get results. Considering all these facts in mind and a suggestion from Rapid Action Force, an indigenous instrument is developed to test stab and impact both properties. The results of the instrument were also compared with the results of the international laboratory for stab and impact properties.

2. Materials and Methods

The study is divided into two parts. In the first part, a survey is conducted among the soldiers of Rapid Action Forces to understand their requirements. In the second part, the instrument was developed and its performance was evaluated by testing body protector samples for stab and impact resistance properties.

2.1 Field Survey

As antiriot body protectors are being used mainly by paramilitary and state & union territory police, it was thought to carry out this survey among the soldiers who are mostly engaged in riots control. There is a special force named 'Rapid Action Force (RAF)'- a specialized wing of the CRPF (Central Reserve Police Force). Its main activities are to deal with riot and crowd control situations. There are many battalions of this force located in different areas in India. Keeping in mind their activity, the survey is carried out among the soldiers of RAF. Three locations were identified. These were Wazirabad in Delhi, Meerut, and Bulandshahar. The findings of this survey are based on the Wazirabad location only. A total of 200 soldiers were surveyed using a well-defined questionnaire. Besides the questionnaire, the one-to-one interview was also conducted with individual solider to understand their actual problem. This survey includes i) Types of activities ii) Fit and Comfort, iii) Risk faced during riots, iv) Level of protection [19]. As the main aim of this work is to develop a stab and impact tester, the findings of only risk faced during riots will be utilized in this study.

2.2 Development of stab and impact tester

For the development of stab and impact tester for body protector testing, the guideline was taken from VPAM KDIW 2004 Edition 2011 standard. This tester has the provision to test the stab resistance property of the body protector by using a knife and impact resistance by a block (like stone) at a different level of energy.

2.3 Collection and testing of samples

Body protector samples were collected from paramilitary forces as well as manufacturers of body protectors. These samples were tested for stab and impact resistance properties using the developed tester as per VPAM KDIW 2004 Edition 2011 standard.

2.3.1 Stab resistance test

As per VPAM KDIW 2004 Edition 2004, the stab resistance test is classified into four classes. These are K1 (25 J strike energy), K2 (40 J strike energy), K3(65 J strike energy), and K4(80 J strike energy). In this study, testing is carried out as per class K1 and K3 using a 0^o of incidence angle. The energy level can be changed by changing the height of drop mass from the striking surface of the sample by keeping the weight of drop mass assembly constant as shown in Table 1. The test is repeated on three specimens of the same lot of samples on the marked position as shown in Fig. 1. The average penetration depth (mm) due to penetration of the knife through the body protector is measured.

Figure 1 - Marking of sample

To calculate the impact energy equation-(i) is used:

E = m.g.h--------(i)

E: Striking energy,

m: Drop mass (mass of the knife with the holder in kg)

g: Gravitational force

h: Falling height (distance between the tip of the blade and the surface of plasticine)

Table 1- Impact energy vs falling height

Weight of drop mass (kg)	Energy levels (J)	Falling height (m)
2.5	15	0.61
	25	1.02
	40	1.63
5.0	65	1.33
	80	1.63
	100	2.04

2.3.2 Impact resistance test

As per VPAM KDIW 2004 standard, the impact resistance test is conducted by dropping a block from the definite height on the body protector. In this test instead of a knife, a block is used. The instrument remains the same. There are 5 classifications in this test. These are W1 (15 J strike energy), W2 (25 J strike energy), W3(40 J strike energy), W4(65 J strike energy), and W5(100 J strike energy). The average deformation depth (mm) due to the strike of the block on the body protector is measured.

The verification of the instrument was carried out by testing the same lot of body protector samples for stab resistance test keeping same energy level at H.P. White Laboratory, lnc., USA, an international laboratory.

3. Results and Discussion

3.1 Field survey to understand the problem of soldiers

During the survey of the soldiers of the paramilitary force, it was observed that the ages of the soldiers were varying from 20 years to 50 years. A 27 % of soldiers were falling in the first age group from 20 to 30 years and 30 % of soldiers were in the age group of 41-50 years. 43% of the maximum number of soldiers was in the age group of 31-40 years. Among the 200 soldiers, 34% were females and 66% were males.

It was also noted that all the respondents wear full-body protector including helmets and carry polycarbonate shields and lathi while handling the crowd. During riots, soldiers face many identified and unidentified threats. The survey showed that 100 % of respondents faced threats from sharp objects and stones in almost all riot situations as shown in Fig. 2. Other than stones and sharp objects petrol bombs and glass bottles are equally

dangerous 90% of respondents reported petrol bombs and 93% bottles. 89% of respondents said that lathi or lathi type material was used by the rioters in some situations.

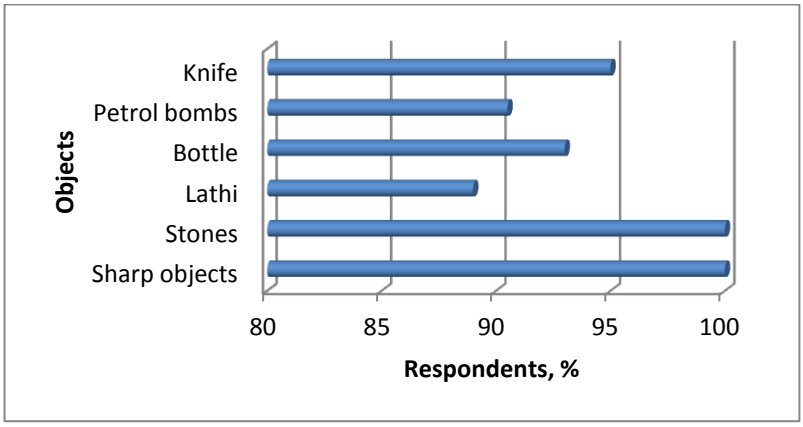


Figure 2 - Various threats faced by respondents

During the survey, 41% of soldiers had told that the anti-riot suit is not capable to give protection to the wearer from sharp objects, stones, lathi, bottles, and petrol bombs. In the case of sharp objects, 40 to 41 respondents felt that the anti-riot body protector gives no protection. One of the factors, which was observed with this survey was that although procurement was carried out as per the guideline of MHA specs No. L.VII.54/2010-12-Prov-R, dated 13, Nov. 2013, there was a gap in the specification as no standard tests are provided to test stab and impact properties of the body protector. The specification was revised as per the suggestions of NITRA. The new specification MHA specs no L-VII-08/2015-19-Prov DA 5 (Part 1) dated 27/09/2019 is provided with testing of stab and impact resistance of body protector. As stab and impact resistance test facilities are not available in India, it was suggested by the Inspector General of Rapid Action Force (RAF) to NITRA to develop this instrument. By this facility, the performance of body protectors can be further improved to save soldiers from injuries due to stabbing and stone-throwing during riots.

3.2 Development of stab and impact resistance tester

The tester includes three main parts namely top, middle, and bottom as shown in Fig. 3. The top part housed a motor assembly to pull the stab and impact assembly from the bottom to a fixed height. The middle part is provided with a cylindrical transparent acrylic drop tube to guide the test tool (drop mass which consists of an engineering knife blade or block the clamping device to hold the knife blade, or spike or block). This part also has a control panel to control various functions of the instrument through the motor. The bottom part consists of a box (350 mm x 400 mm x 150 mm) filled with plasticine clay also called backing material. Plasticine is non-hardening modeling clay. This backing material is used to determine the deformation depth due to block and the penetration depth due to the strike of the knife on the body protector. The angle of incidence can be adjusted by the gear system provided with the box (Fig. 4) given in the bottom part of the tester.

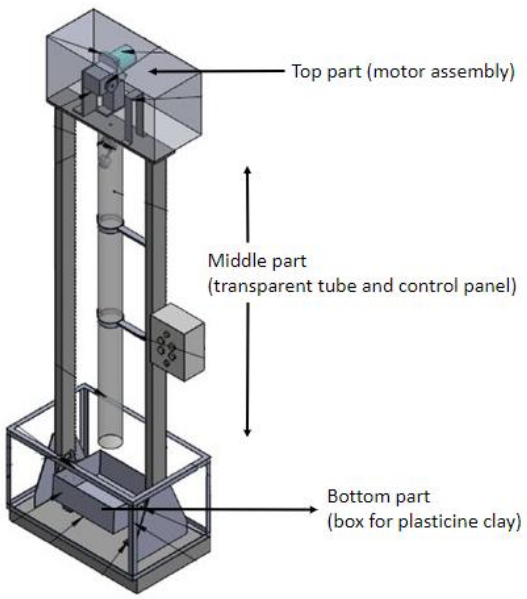


Figure 3 - Stab and impact test assembly

Figure 4 - Box provided with gear system to adjust the angle of incidence

A steel ball (diameter 63.5 ± 0.05 mm, mass 1039 ± 5 g) is also fabricated (Fig. 5) to test the plasticity of the plasticine before starting testing the body protector. This ball is allowed to fall on the planar and horizontal surface of plasticine at a height of 2000 ± 5 mm. This test is repeated 5 times and the deformation depth of plasticine is measured. If all the 5 tests show the deformation depth 20 ± 2 mm, the plasticity of the plasticine is accepted.

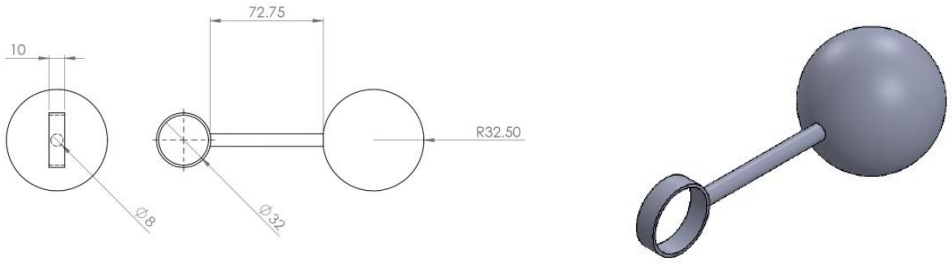
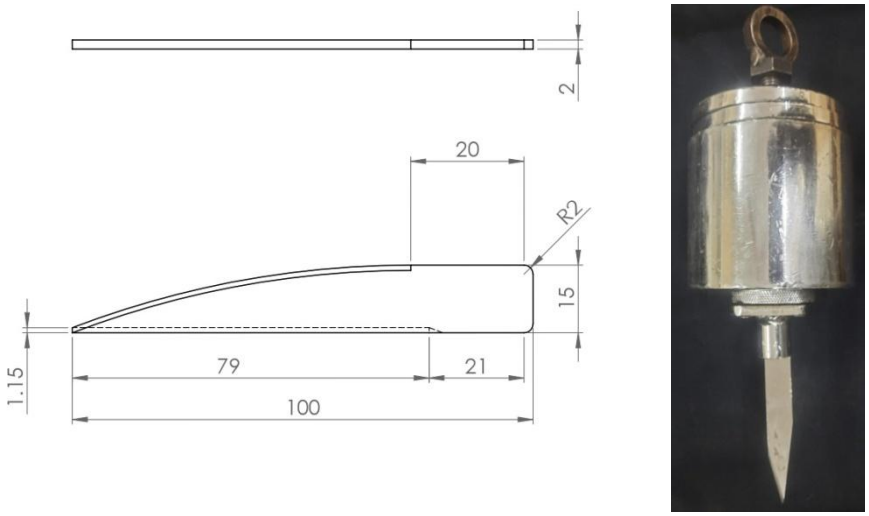


Figure 5 - Dimension (in mm) and picture of steel ball

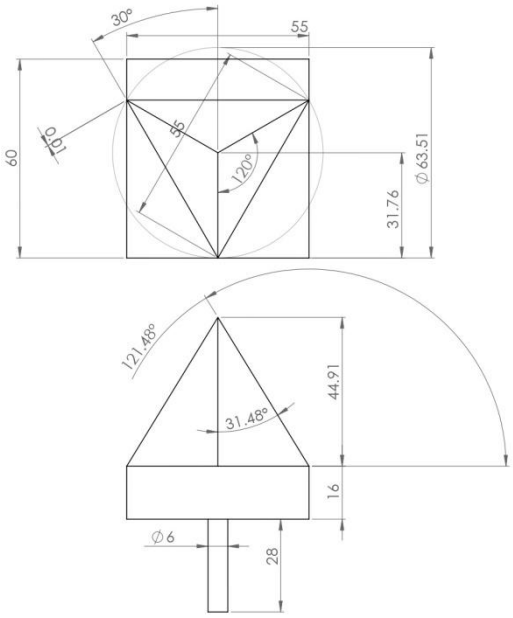
A stab resistance test was carried out with a standard Knife. The blade of this knife has specific dimensions and sharpness as shown in Fig. 6. The complete assembly of the knife with drop mass is also shown in Fig. 6.



Dimensions in mm for making knife Knife with drop mass

Figure 6 - Knife used for stab test

The impact resistance test was carried out with a block. The block used in this test has specific dimensions as shown in Fig. 7. The complete assembly of the block with drop mass is also given in Fig. 7.



Dimensions in mm for making block Block with drop mass

Figure 7 - Block used for impact test

A complete picture of the developed stab and impact tester is shown in Fig. 8.

Figure 8 -Picture of developed stab and Impact tester

3.3 Testing of body protectors on developed stab and impact resistance tester

Test specimens of body protector were conditioned for 12 hrs at 20 ± 2 ºC and 65 ± 5% relative humidity before testing. Tests were performed on the front and backsides of the chest protectors of the body protector.

3.3.1 Stab resistance test

To check the workability of the fabricated stab and impact tester, 3 specimens of one sample of body protectors were tested at 25 J and 65 J strike energy levels with an impact angle of incidence of 0^o on the test panel (the angle between striking knife and horizontal panel is 90^o). Samples of the same lot were also sent to the International laboratory. The results of these samples are given in Table 2.

Table 2 - Stab resistance test at 0^0 incidence angle on a test panel

Test parameter	Strike energy (joules)	Penetration depth, mm
		Test results (no. of Specimens)

		1	2	3
Test carried out on developed Stab and Impact resistance tester	25	49	45	52
Average penetration depth, mm		48.7		
Standard deviation		3.5		
Test carried out in the International laboratory		45	49	53
Average penetration depth, mm		49.0		
Penetration depth, mm				
Test carried out on developed Stab and Impact resistance tester	65	59	57	60
Average penetration depth, mm		58.7		
Standard deviation		1.527		
Test carried out in the International laboratory		62	62	47
Average penetration depth, mm		57.0		
Standard deviation		8.66		

From Table 2, it is clear that the average penetration depth is around 48.7 mm and 58.7 mm for the sample tested using the developed tester at 25 J and 65 J respectively. The same lot samples when tested at the international laboratory, the results of penetration depth were 49 mm and 57 mm at 25 J and 65 J respectively. The standard deviations of the test results are also given in Table 2. The value of standard deviation on the lower side indicates the reproducibility of results. Fig. 10 indicates the stab test performed on the body protector.

Figure 10 - Performing stab test on body protector

3.3.2 Impact resistance test

For this study, W 5 class is used to analyze the impact test. The impact resistance properties of 3 specimens of one sample were tested on a developed stab and impact tester at 100 J strike energy level. Results are shown in Table 3. From the table, it is clear that there is the reproducibility of test results. The standard deviation among the test rest results of specimens was found to be 0.75 when specimens were tested on a developed stab & impact tester.

Table 3 - Impact resistance test at 0^0 incidence angle on a test panel

Test parameter	**Strike energy (joules)**	**Deformation depth, mm**		
		Test results (no. of Specimens)		
		1	**2**	**3**
Test carried out on developed Stab and Impact resistance tester	100	9	7.5	8.2
Average deformation depth, mm		8.2		
Standard deviation		0.75		

4. Conclusion

An indigenous cost-effective tester is developed to determine stab and impact resistance properties of body protectors. The tester is capable to provide useful information about the stab and impact resistance properties of the body protectors to the manufacturing industry as well as procurement agencies. Before developing this tester, a preliminary survey was carried out amongst the Rapid Action Forces soldiers to get their actual requirements related to the safety aspects. The results obtained from this developed tester were also verified with the results of the same lot samples tested in international laboratories.

5. Acknowledgment

Authors are thankful to DIGP (Prov & Accts) of Rapid Action Force for permitting survey their soldiers.

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