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Suitability test of gelatin as a test simulant in two block sizes when fired with a very high-energy hunting bullet > 5000 J and test of a modified crack length measurement method

- 15.03.2024, Berlin, DDW
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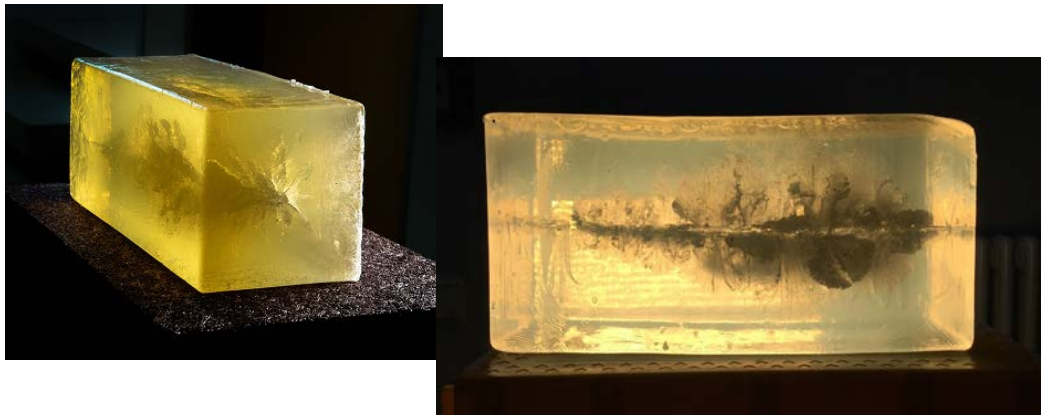
  - Unit Feed and Feed Additives
  - Department Safety in the Food Chain



Structure

1. Aims
2. Hypotheses
3. Material and methods
4. Implementation
5. Results
6. Summary
7. Conclusion

Aims

BfR Research project part I 2019/2020

Preconditions

- **Generally much higher bullet energies of hunting rifle bullets compared to police bullets**
- **Simulant: gelatin blocks (20 % gelatin), dimensions: 35 cm x 15 cm x 15 cm**

Questions

1. To what extent does the gelatin block size influence the energy output profiles of hunting rifle bullets and the reproducibility of the results?

2. Does the modified method of crack length measurement according to TR cartridge 9 mm x 19, reduced-pollutant[1] on a photo basis passes the practical test (independent of time and location)?

[1] Technische Richtlinie Patrone 9 mm x 19, schadstoffreduziert“ des Polizeitechnischen Instituts (PTI) der Deutschen Hochschule der Polizei (DHPol), 9/2009

Hypotheses

When testing two gelatin block sizes by firing a very high-energy hunting bullet, it is expected that

a) the small block size will not withstand the very high energy input of the bullet and that the block will rupture.

b) the large block size will withstand the energy input of the bullet.

Material and methods

Parameters

Shooting channel	Beschussamt Ulm (BA Ulm)
Shooting distance:	15 m
Measuring barrel:	DEVA[1] (barrel length 600 mm, twist length 254 mm)
Loaded projectiles:	RWS .338 Lap. Mag. SPEED TIP PRO 16,2 g (loading: DEVA), partial fragmentation bullet
Bullet target velocity (V_{ziel}):	800 m/s
Number of shots:	3 shots per block size
High-speed camera videos:	Photron Fastcam SA5

[1]Deutsche Versuchs- und Prüf-Anstalt für Jagd- und Sportwaffen e.V., Altenbeken

Material and methods

Test simulant

Production of three gelatin blocks (20 %) each in the following dimensions:

- **small block:** length: 35 cm, width: 15 cm, height: 15 cm
- **large block:** length: 40 cm, width: 25 cm, height: 25 cm

Implementation, 09.-12.12.2019 at Beschussamt Ulm

Production of gelatin blocks according to the instructions in Annex 9 of the Technical Guideline Cartridge (2009[1])

Impressions

Gelatin Gelita Typ Ballistic 3


Mixing the gelatin (20 %)


Mixing the gelatin (20 %) after swelling


Stainless steel mold – large block size

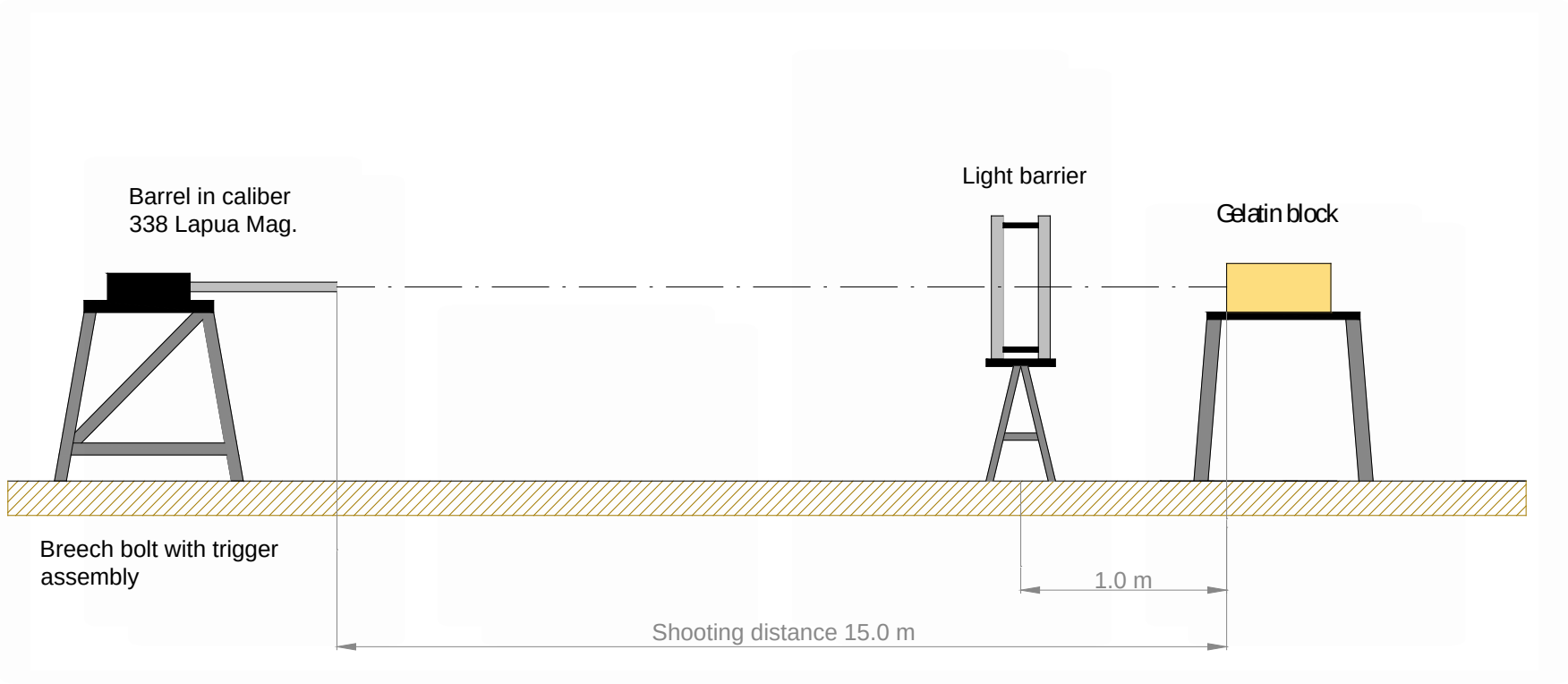

Removing the block from the mold


Wrapping the blocks in PE film

Storage in a climate chamber

[1] Technische Richtlinie Patrone 9 mm x 19, schadstoffreduziert“ des Polizeitechnischen Instituts (PTI) der Deutschen Hochschule der Polizei (DHPol), 9/2009

Implementation
Bombardment of the gelatin blocks

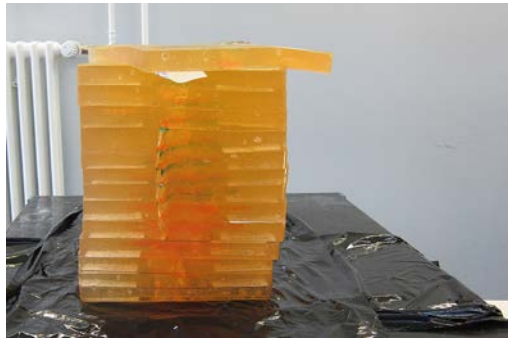


Sketch of the experimental setup for study I (Drawing not to scale).

Implementation
Cutting the gelatin blocks

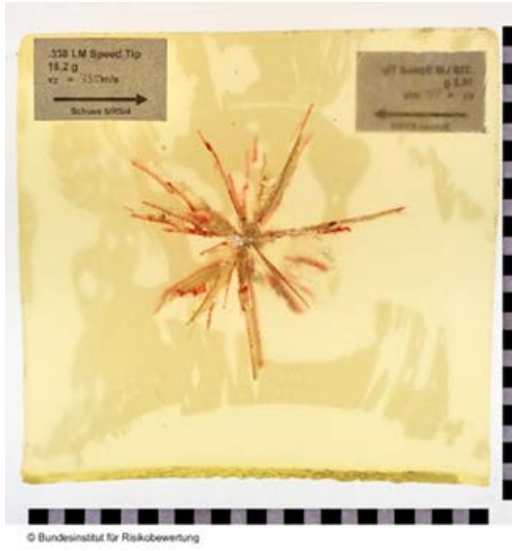
Cutting mashine for small blocks

Cutting device for large blocks



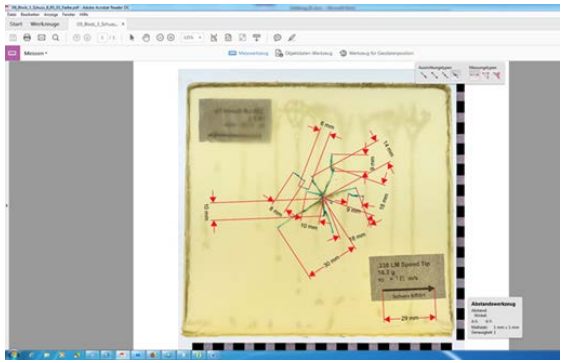
Gelatin block slices each 2.5 cm thick

Implementation
Crack length measurement



a) Method according to the Technical Guideline Cartridge 9 mm x 19 (2009)

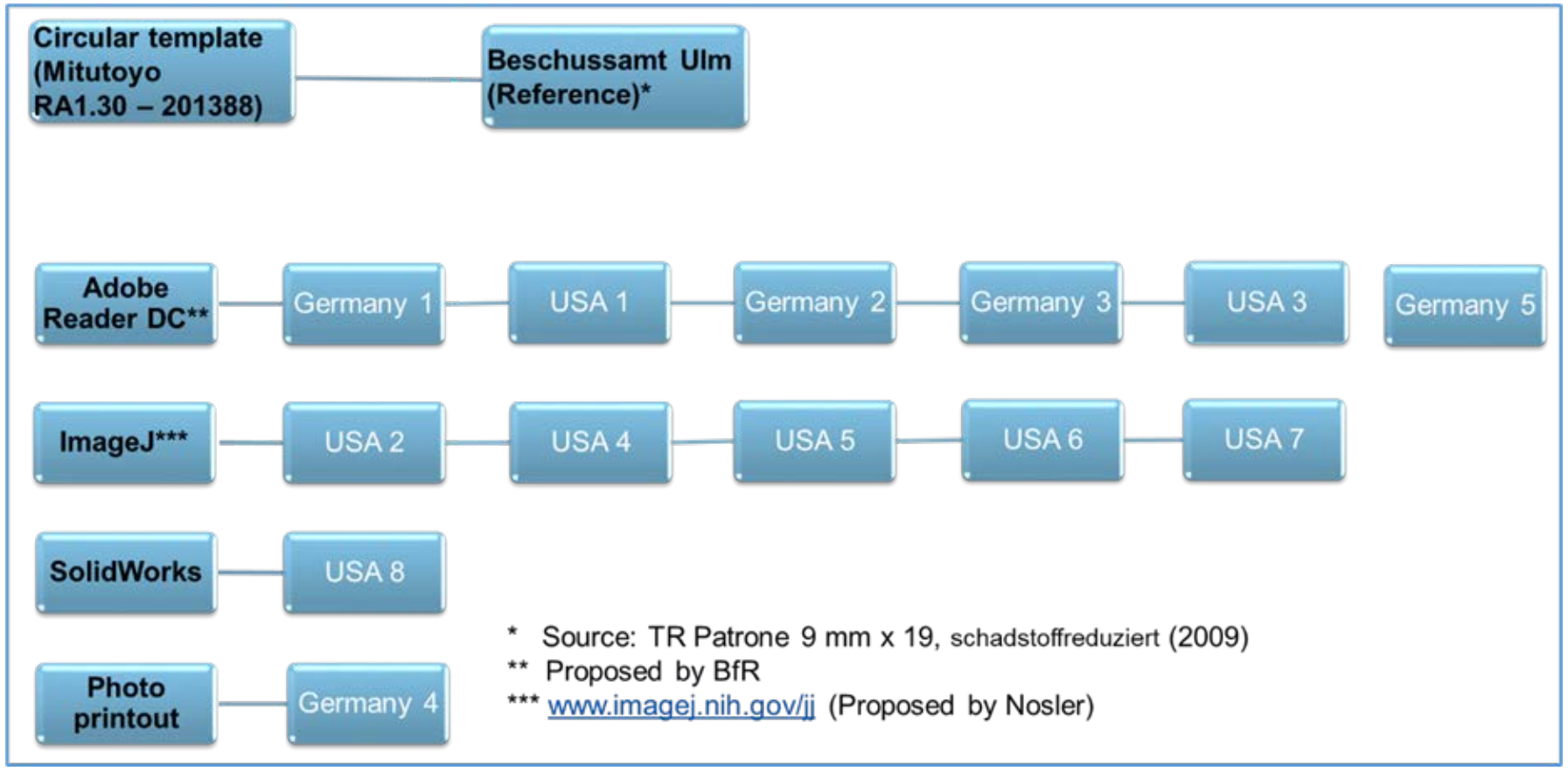
b) Standardized modified method on photo basis



<u>Measurement tool</u>
Adobe acrobat Reader

Implementation

Crack length measurements performed with different measurement tools



Implementation

Example of a data sheet for entering the crack lengths [mm] on a photo basis (true to scale)

				j: crack length number																					
Slice number i	Penetration depth	Side	Arrow	j=1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	$S_{i,front}$/ $S_{i,back}$	$L_{Total,i}$
1	0,0 cm	front		24,2	22,8	39,1																		86,108	128,41
	2,5 cm	back		16,1	11,1	39	4,23	22	11,6	24	23,3	19,3												170,71	
2	2,5 cm	front		25,3	22,5	27,8	24,5	13,8	40,2	11,1	18,8													184,02	290,83
	5,0 cm	back		55,4	26,4	21,9	47,6	52,1	40,8	19,3	36,6	29,1	68,4											397,64	
3	5,0 cm	front		59,1	71,4	15,3	7,07	61,5	36,5	31,5	50,1	56	14,5	16										418,91	555,73
	7,5 cm	back		34,3	45,9	17,9	27,6	45,2	16,1	78,1	28,2	25,1	29,7	65,1	41,9	66,5	26,8	72,7	71,6					692,55	
4	7,5 cm	front		14,4	31,9	33,6	72,4	12,5	24,7	44,5	44,9	47,1	9,23	69	25,8	23,7	24,8	81,7	61,6	40,3				662,19	660,86
	10,0 cm	back		80,1	88,9	18,1	47,7	72,8	37,2	13,5	52,3	23,3	44,2	34,8	34,1	50	62,5							659,54	
5	10,0 cm	front		64,8	78,6	10,4	30,9	24,8	50,2	30,5	34,9	23	50,4	82,8	22,2	78,5	19,4	21,6						623,07	664,39
	12,5 cm	back		80,9	20,3	81,5	21,1	14	59,3	37	53,6	62	61,1	79,3	21,1	62,7	51,9							705,72	
6	12,5 cm	front		62,7	44,4	86,3	59,1	9,25	58,7	56,9	29,7	19,4	88,9	28,6	115	43,8								702,23	703,98
	15,0 cm	back		49	112	42,4	59,6	15,8	46,4	44,4	50,8	8,75	17,2	44,8	51,9	64,6	21,4	26,1	23,5	11,6	15,8			705,72	
7	15,0 cm	front		50,3	31,9	23,8	66,2	13,1	42,3	22,2	65,4	21,4	64,3	47,5	33,7	8,07	88,7	10,2	20,5	112				721,42	732,09
	17,5 cm	back		88,4	33,5	60,3	32,8	44,8	36,4	20,9	44	84	16,6	60,3	29,1	22,2	48,3	87,4	33,6					742,77	
8	17,5 cm	front		25,8	44,1	8,12	53	26,2	41,9	13,2	76,7	20,4	58,3	15,4	64,6	27,7	16,6	16,4	85,4	29,7				623,22	579,31
	20,0 cm	back		115	67,1	43,3	21,1	12,8	28,4	93	21,1	39,1	34,3	23,2	36,7									535,4	
9	20,0 cm	front		17,5	17	22,3	27,7	39,2	21,3	95,7	42,8	16,5	25,7	57,3	116									499,45	415,91
	22,5 cm	back		68,4	49,3	38,8	95,2	20,2	16,3	44,1														332,36	
10	22,5 cm	front		117	42	13,3	92,7	16,7	34,1															315,42	345,17
	25,0 cm	back		73	24,2	40,1	15,7	75,1	33,4	58,7	20,9	33,8												374,93	
11	25,0 cm	front		47	28,6	34,3	35,1	10,4	13,7	11,7	18,9	58,9	72,9	26,4										358	306,58
	27,5 cm	back		72,3	6,8	22,3	69,9	18,2	57,6	8,09														255,16	
12	27,5 cm	front		74,7	9,57	60,8	17,1	65,7	9	15,5	5,73													258,13	237,19
	30,0 cm	back		67,4	33,4	40,5	52,2	11,9	10,8															216,25	
13	30,0 cm	front		69,4	47,2	24,3	52,5																	193,39	233,68
	32,5 cm	back		52,6	47,3	12,7	14,3	21,9	4,86	14,6	65,6	19,8	5,12	4,68	8,15	2,26								273,97	
14	32,5 cm	front		44,1	52,5	27	32,1	16,2	15,2	21,8	25,4	34,6												268,88	303,81
	35,0 cm	back		42	13,6	17,1	35,2	3,33	10,3	30,7	17,9	44,6	27,5	17,7	12,3	35,5	30,8							338,75	
15	35,0 cm	front		48,2	8,84	15	28,4	34,4	17,3	15,1	36,2	27,2	9,99	16,1	20,6									277,22	231,32
	37,5 cm	back		27,3	16,6	28,9	12,8	26,4	10,7	22,6	8	32,2												185,42	
16	37,5 cm	front		21,6	19,6	16,4	7,39	9,24	31,3	7,13	6,81	16,5	21,5											157,47	115,01
	40,0 cm	back		20,7	15,3	10,5	8,48	17,6																72,554	
BfR	Bundesinstitut für Risikobewertung			Beschussamt Ulm											12.12.2019									L_{Total}	6504

Results

First oberservations

Highspeed-camera-recordings:

Two examples: Bombardment of a small and a large gelatin block size

Video 1: Small gelatin block size_Ulm_shot3_block_3_791,5m-s.mp4

Video 2: Large gelatin block size_Ulm_shot4_block_1_797,28m-s.mp4


15000 fps
1024 x 496
frame : 0
+0.000 ms
Time : 00:01
BfR

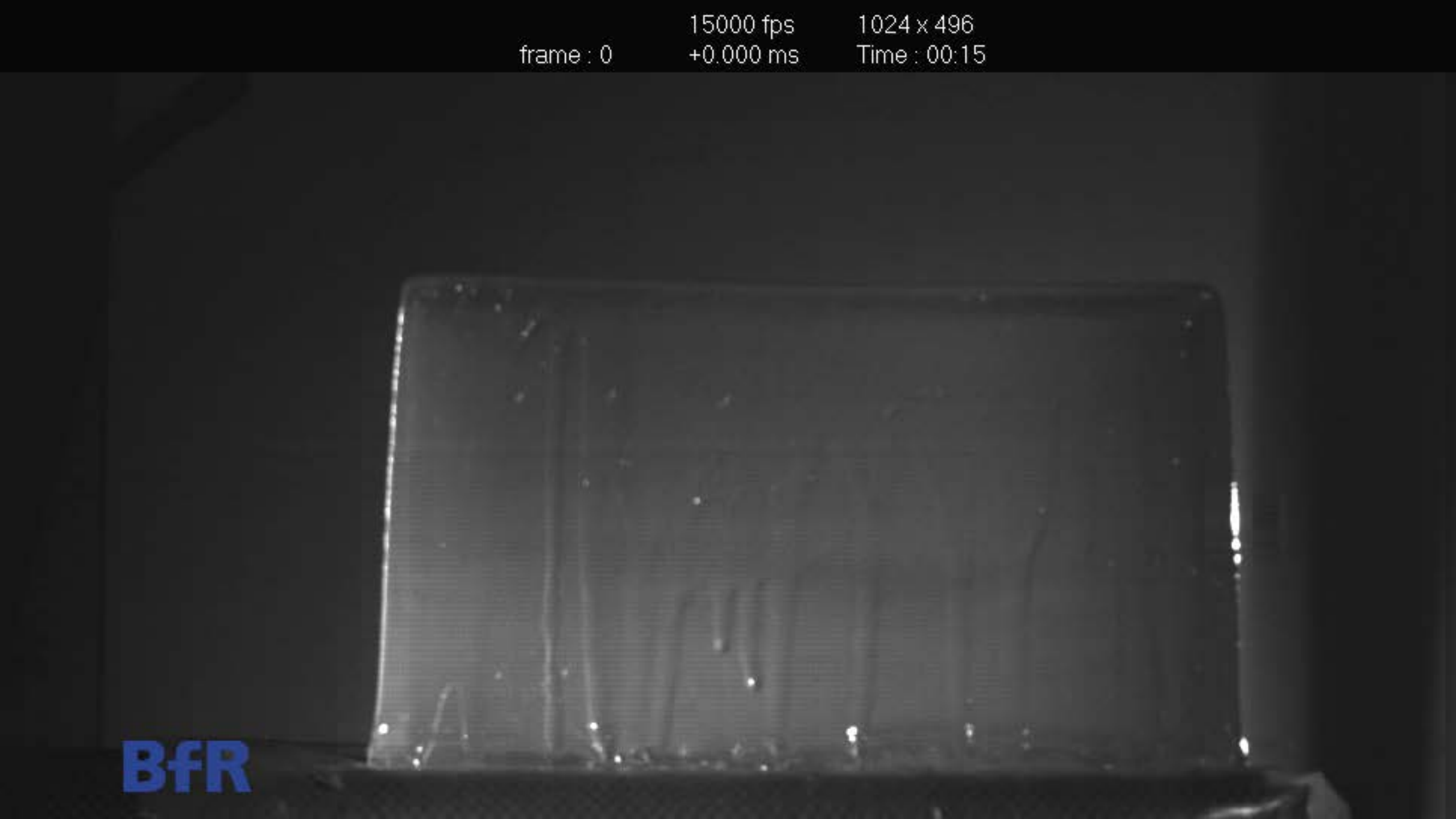
Results
First oberservations

Highspeed-camera-recordings:

Two examples: Bombardment of a small and a large gelatin block size

Video 1: Small gelatin block size_Ulm_shot3_block_3_791,5m-s.mp4

Video 2: Large gelatin block size_Ulm_shot4_block_1_797,28m-s.mp4


15000 fps
1024 x 496
frame : 0
+0.000 ms
Time : 00:15
BfR

Results

First observations

The result was surprising. Our working hypothesis was not confirmed with regard to the reaction of the small blocks.
The small block size did not burst, but remained as a block. On closer inspection, however, the surface showed cracks.

Only in one large block did the crack lengths remain within the block and could be evaluated according to Technical Guideline Cartridge 9 mm x 19, Appendix 9.

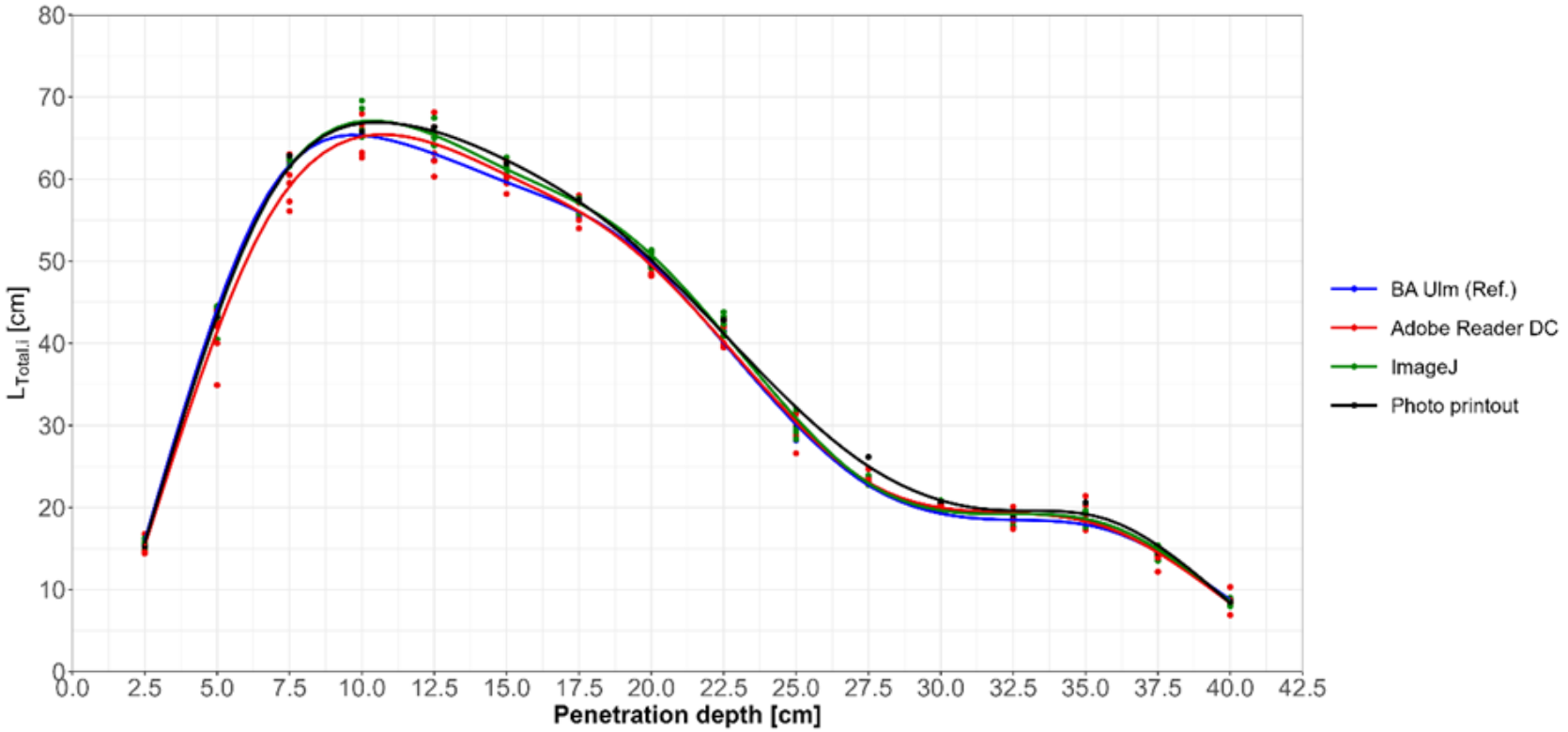
Note

It was not the aim of this investigation to evaluate the effectiveness of the bullet.

[1] Technische Richtlinie Patrone 9 mm x 19, schadstoffreduziert“ des Polizeitechnischen Instituts (PTI) der Deutschen Hochschule der Polizei (DHPol), 9/2009

Results

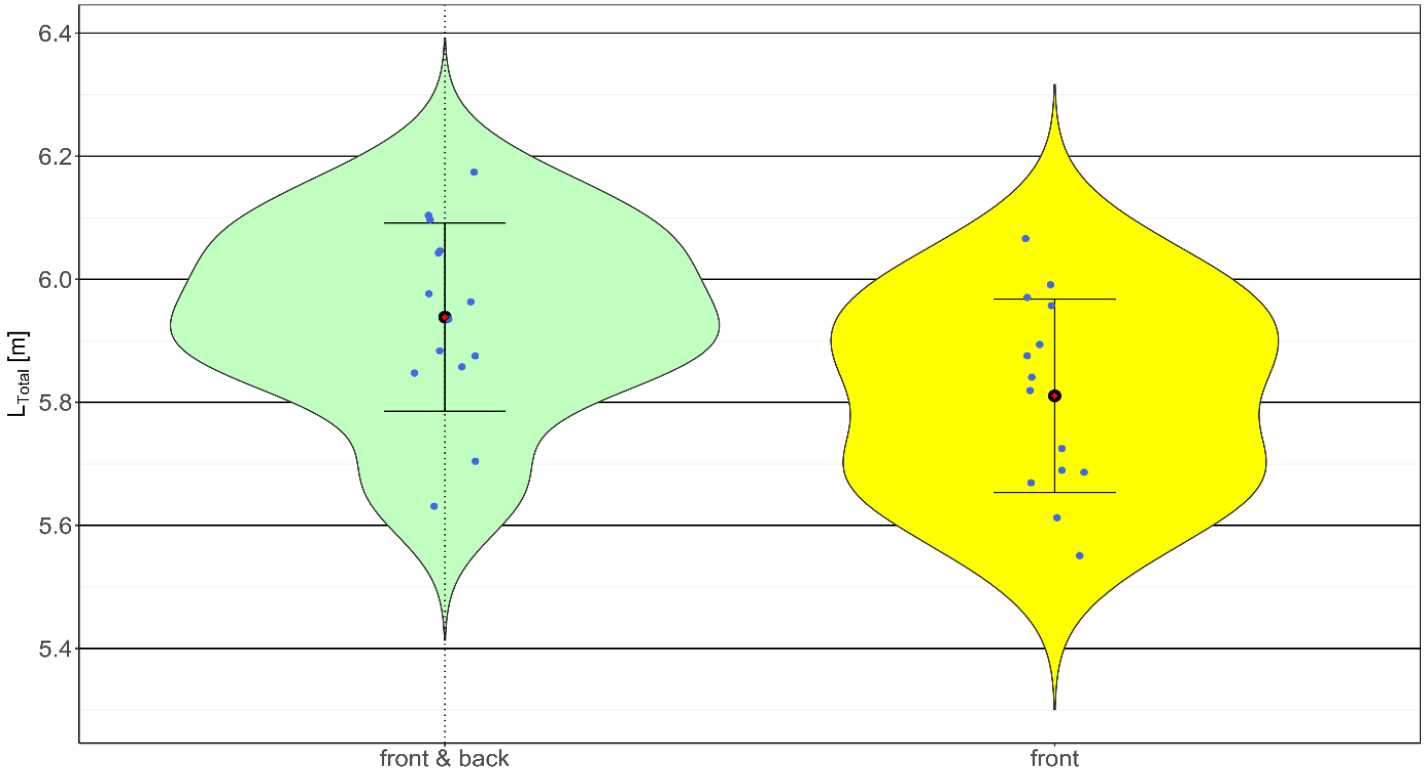
Crack length measurements – Comparison of measuring tools



Comparison of measurement tools for determination of crack lengths $L_{Total.i}$ along the penetration depth. Points: observed crack lengths measured with different tools (red: Adobe Reader DC N=6, green points: ImageJ N=5, black points: Photo printout N=1, blue point: Reference method), solid lines: fitted smooth curve through points.

Results

Comparison of the total crack length of the front and backside of the slice



Total crack lengths measured on the front and back (light green) compared to crack lengths that were only measured on the front (yellow). Black error bars representing the standard deviations of the means (black dot), red dots represent the median, blue dots (jittered) represent raw data of individual crack length analyzers, shape of violin plots represent the density distribution.

Results
Frequency of cracks and total crack length depending on crack lengths analyzer

	Number of cracks < 6 mm	Number of cracks >= 6 mm	Total number of cracks	Total Crack length L_{Total} [m]
Reference	0	323	323	5.9
Germany 1	6	327	333	6.0
USA 1	1	294	295	5.8
USA 2	1	313	314	6.1
USA 3	45	416	461***	6.2
Germany 2	7	334	341	5.9
USA 4	3	336	339	6.1
USA 5	7	364	371	6.0
USA 6	20	436	456***	5.9
USA 7	8	338	346	6.0
Germany 3	3	317	320	5.7
Germany 4	3	327	330	6.0
Germany 5	1	300	301	5.6

*** p<0.001 (generalized additive model fitted with negative binomial family, R^2=93%)

Summary

Blocksize

- The two gelatin block sizes used differ in terms of their load capacity at very high energy input (> 5000J) of a hunting bullet. In all three small blocks, crack lengths cut through the surface(s) of the block. Crack lengths can therefore not be measured as they are not completely mapped.
- The firing results are only reproducible when the large block size is used. A high number of firing repetitions is likely.

Crack length measurements tools

- The crack length measurements according to TR Cartridge 9 mmx 19 (2009)[1] modified photo-based method (BfR method), are comparable with the reference method on site and can also be compared internationally with the results of the ImageJ measuring tool (USA). Advantage: The measurements are independent of time and location and can be verified. Disadvantage: The modified method is time-consuming due to the photography of each gelatin block slice side.

[1] Technische Richtlinie Patrone 9 mm x 19, schadstoffreduziert“ des Polizeitechnischen Instituts (PTI) der Deutschen Hochschule der Polizei (DHPol), 9/2009

Summary

Statistics

- As the results of crack length measurements (Reference method[1], modified method, ImageJ measurement tool and print out measurement) could only be statistically verified on one block, therefore they must be cross-checked with further bombardment results.
- The smallest crack lengths (< 6 mm) have statistically only an insignificant influence on the measurement results, so that the measurements of these crack lengths can be omitted.

[1] Technische Richtlinie Patrone 9 mm x 19, schadstoffreduziert“ des Polizeitechnischen Instituts (PTI) der Deutschen Hochschule der Polizei (DHPol), 9/2009

Conclusion

- The smaller gelatin block size is not suitable for testing very high-energy hunting bullets. The reproducibility of the firing results when using the large block size needs to be checked before testing.
- Crack lengths <6 mm are not statistically relevant in relation to the total crack length of the block and therefore do not need to be measured.
- Our statistical evaluations indicate a tendency that would mean a considerable advantage (time saving) for the crack length measurements, namely that the backs of the gelatin block slice sides do not need to be measured. This result still needs to be confirmed using a larger sample and will be evaluated in the second part of the study.

Acknowledgement

Ulm
Beschussamt Ulm

DEVA
Deutsche Versuchs- und Prüf-Anstalt für Jagd- und Sportwaffen e.V.

DJV
Deutscher Jagdverband

OMI -Mellrichstadt

RWS GmbH Ignition Technology

SAAMI
SPORTING ARMS AND AMMUNITION MANUFACTURERS' INSTITUTE, INC.
SINCE 1926
Sporting Arms and Ammunition Manufacturers' Institute

BfR
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- soundcloud.com/risikobewertung

Supplementary slides (in case of questions)

Explanation of the video3 sequence

Bombardment: Comparison of small gelatin block/large gelatin block/soap block

Bullet: RWS .338 Lapua Magnum SPEED TIP, bullet weight: 16.2 g

Date and place of shooting: 12.12.2019, Beschussamt Ulm: High-speed camera recordings: Deutsche Versuchs- und Prüf-Anstalt für Jagd- und Sportwaffen, Altenbeken

1) Video: Gelatine-klein_Ulm_Schuss2_Block_2_793,63m-s.mp4

Target velocity: Vz = 793.63 m/s

Block size - gelatin block (20 % gelatin): 35 x 15 x 15 cm (LxWxH)2)

2) Video: Gelatine-groß_Ulm_797,28m-s.mp4

Target speed: Vz = 797.28 m/s

Block size - gelatin block (20 % gelatine): 40 x 25 x 25 cm (LxWxH)

Production of gelatin according to recipe Technical Guideline "Cartridge 9 mm x 19, reduced harmful substances", as at: September 2009)

3) Video: Soap block

Target speed: Vz =799m-s

Block size: 40 x 25 x 25 cm (LxWxH)

Production of the soap block according to Permatin recipe: Soap manufacturer Walde, Innsbruck, Austria

Material and methods
Time frame

Recorded production of the gelatin blocks at BA Ulm:

December 09, 2019: two large gelatin blocks and one small gelatin block

December 10, 2019: one large block and two small gelatin blocks

Time period: between 7:30 am and 10:00 am (mixing and swelling of the gelatin)

Procedure: 1. mixing and swelling of the gelatin (20 %), 2. filling of the stainless steel molds 3. cooling to 20° C ± 1° C in the block core 4. removal from the molds 5. wrapping in PE film and storage in a climate chamber (make: CTS type: CW-40/3 no.: 091131) at 60 % ± 5 % humidity and 15° C ± 1° C until bombardment.

Minimum storage period for small blocks before bombardment: 18 h

Requirement: 15° C ± 1° C core temperature of the blocks

Versuchsdurchführung

Statistical analyses /Analyses of crack length

Formula:

$$L_{Total.i} = \frac{1}{2} * (S_{i.front} + S_{i.back}) \quad (1)$$

where

$$s_{i.front} = \sum_{j.front} L_{i.j.front} \quad (2)$$

$$s_{i.back} = \sum_{j.back} L_{i.j.back} \quad (3)$$

For each block, the total crack length L_{Total} results from the sum of the mean values per slice (Formula 4).

$$L_{Total} = \sum L_{Total.i} \quad (4)$$

https://rws-munition.de/rws-jagd-bereich/rws-jagdmunition/rws-buechsenpatronen-fuer-den-jaeger/Product/show/speed-tip-professional/338-lapua-mag.html

RWS .338 Lap. Mag. SPEED TIP PRO 16,2g

Art. Nr: 2403863

Datenblatt > HÃ¤ndler >

Anwendungsgebiete

★★★ Rotwild, Oryx, Elch, BÃ¤r

★★ Schwarzwild, Damwild, Gamswild

★ BÃ¼ffel

		50m	100m	150m	200m	250m	300m
	100m	-0,8	âŠ•	-2,7	-9,3	-19,8	-34,8
GEE	190m	1,2	4,0	3,3	-1,2	-9,8	-22,7

BC-Wert: 0,566
LaufLÃ¤nge: 650 mm

Eigenschaften

Geschosstyp blei/bleifrei	Bleihalt. Teilzerleger
Geschosscharakter	Herausragende Augenblickswirkung - hohe Tiefenwirkung
Geschossgewicht	Leicht
Wildbretschonung	Unterschiedlich
Stoppwirkung	Sehr hoch
RÃ¼ckstoÃŸ	Stark
Tiefenwirkung	Sehr hoch
Ausschusswahrscheinlichkeit	Sicher
Schnitthaar	Nein

Geschwindigkeit

	0m	50m	100m	150m	200m	250m	300m
V [m/s]	885	857	830	804	778	752	727

Energie

	0m	50m	100m	150m	200m	250m	300m
E [J]	6344	5949	5580	5236	4903	4581	4281

Summary

Statistics

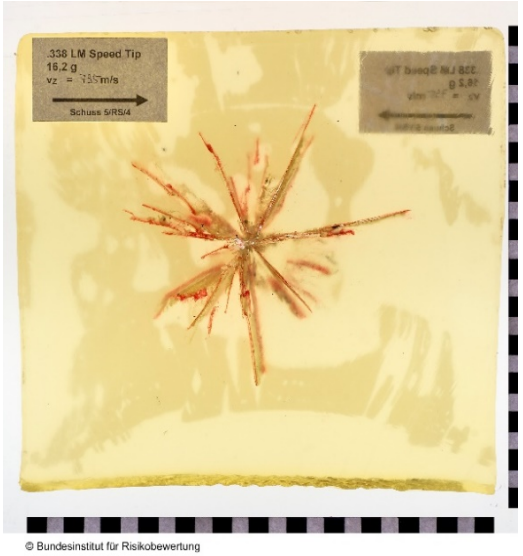
- Statistically, the slice thickness to be cut for the crack length measurements, which is 2.0 cm according to TR Cartridge 9 mm x 19 (2009)[1], has no effect on the measurement results with a slice thickness of 2.5 cm. This procedure is possible when using the statistical GAM prediction model. In addition, the slightly thicker discs allow easier handling and minimize the risk of changes in crack formation.

[1] Technische Richtlinie Patrone 9 mm x 19, schadstoffreduziert“ des Polizeitechnischen Instituts (PTI) der Deutschen Hochschule der Polizei (DHPol), 9/2009

Versuchsdurchführung

Risslängenmessungen

Bestimmung der Risslängen gemäß den Vorgaben nach der TR Patrone 9 mm x 19 (2009) im Beschussamt Ulm (Referenz) sowie durch Anwendung der veränderten Methode nach TR Patrone (2009) auf Fotobasis (BfR-Methode).
Vor der Risslängenmessung wurde von jeder farblich markierten und beschrifteten Gelatineblock-scheibenseite ein standardisiertes Foto nach dem beschriebenen Verfahren aufgenommen (Abb. 2).



Unterschied zur TR Patrone (2009):

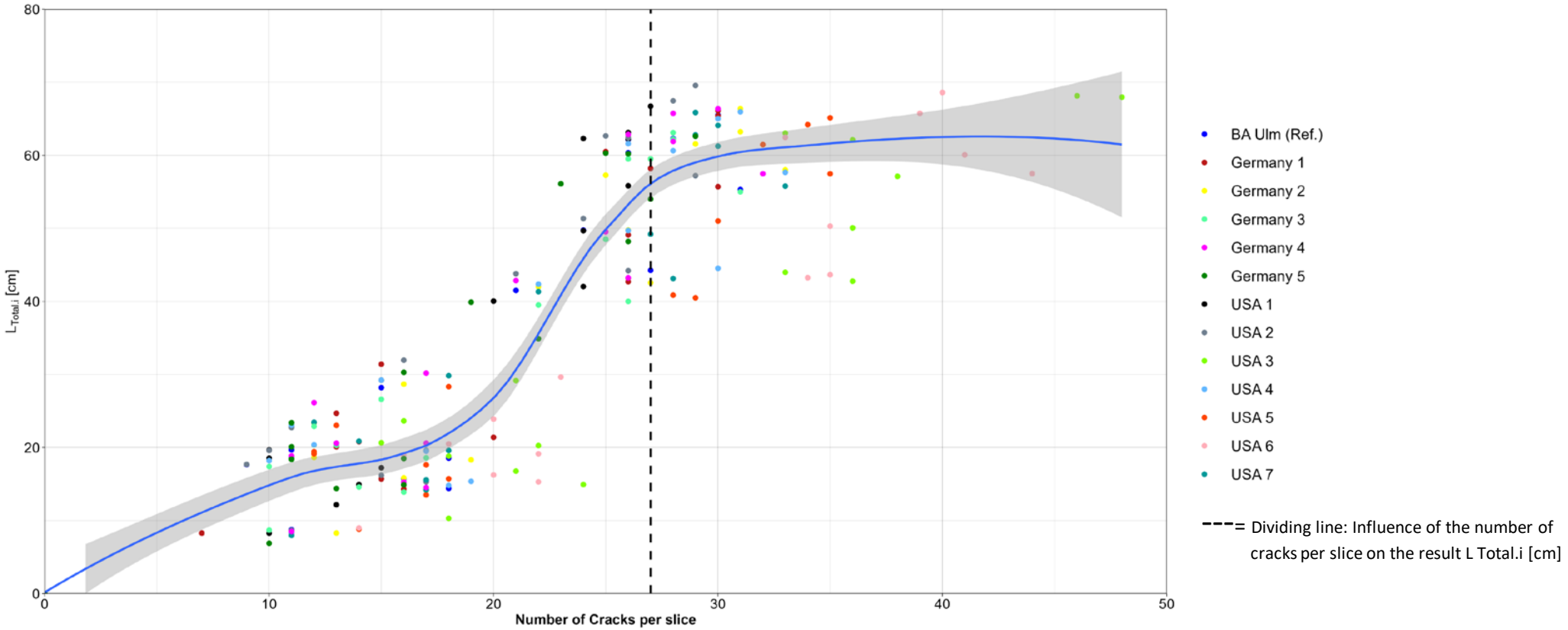
Die Wahl der Scheibendicke von 2,5 cm wurde als Kompromiss zwischen Genauigkeit und Kosten gewählt.

Nachdem die Risslängen in den Blöcken 1 und 2 auf den Vorder- und Rückseiten der Gelatineblockscheiben rot markiert wurden, wurden die Risslängen auf den Rückseiten der Scheiben in Block 3 im Laufe der Messungen grün markiert, um die farbigen Risslängen der Vorderseiten besser von denen der Rückseiten zu unterscheiden.

Abb. 2. Ansicht der standardisierten Fotografie (Gelatineblockscheibenseite)

Results

Relationship between crack length ($L_{Total.i}$) and number of cracks per slice



Single points denotes the raw data of individual crack length analyzers, Solid blue line: predicted smoothed crack lengths on gelatin slices with 95 % confidence intervals of the fitted smoother.

Acknowledgement

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Note: The participation of the US ammunition manufacturers in the testing of the modified method of crack length measurements (BfR) does not mean that they endorse or otherwise support the method used or any conclusions reached.

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