PROBLEMY MECHATRONIKI
UZBROJENIE, LOTNICTWO, INŻYNIERIA BEZPIECZEŃSTWA

ISSN 2081-5891 **8, 3 (29), 2017, 57-72**

PROBLEMS OF MECHATRONICS
ARMAMENT, AVIATION, SAFETY ENGINEERING

Concept of a UTM MMR Training Conversion Kit for the MSBS-5.56 Assault Rifle

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Received by the editorial staff on 31 May 2016.
The reviewed and verified version was received on 2 February 2017.

DOI 10.5604/01.3001.0010.4110

Abstract. This paper shows an overview of the state of the art in the UTM MMR (Ultimate Training Munitions Man Marker Round) 5.56 mm marker cartridges with a description of its design and operating principle. This paper also includes an overview of several UTM training conversion kits enabling the use of UTM MMR ammunition in 5.56 mm rifles, complete with a description of their design, operating principle, and safety precaution solutions for users. Based on a series of analyses, a UTM MMR training conversion kit was developed and described for the MSBS-5.56 assault rifle.
Keywords: firearms, assault rifle, training marker ammunition, training conversion kit

This work has been compiled from the paper presented during the 11th International Armament Conference on Scientific Aspects of Armament and Safety Technology, Ryn, Poland, September 19-22, 2016.

1. INTRODUCTION

The training marker ammunition brands that are in widespread use at present include Simunition FX, ATK FOF (Force on Force), and UTM MMR. Training marker ammunition has been developed for firearms training regimes which accurately simulate real-life dynamic combat scenarios (with shooting human training) and are called FOF (force on force) training. The key characteristics of training marker ammunition is a low projectile weight and a low muzzle velocity, which result in the kinetic energy of impact being relatively low, in the range of several joules only. Upon impact, the polymeric shell of the projectile breaks, and the marking compound contained inside marks the target being hit. The low kinetic energy ranges of training marker rounds make them safe for human health, provided that certain precautions are applied, e.g. full face masks (with a specific focus on eye protection), guards, and a double layer of clothing. Other advantages of training marker ammunition include small hazardous zone areas and a low demand for dedicated training infrastructure. Marker round-based training with military and law enforcement firearms helps to develop appropriate reactions in firearms operators. The disadvantages of this solution are the necessary conversion of live-round firearms and the short range of the emulated projectile trajectories; moreover, training marker ammunition is significantly more expensive than live ammunition.

These drawbacks are significantly outweighed by the fact that training marker ammunition enables real-life training conditions with extremely favourable effects on the trainees; hence, training conversion kits and their marker rounds are commonly used around the world.

The reduced muzzle velocity of marker round projectiles is achieved by a propellant batch per round that is lower than in live rounds; this requires a piston cartridge case which boosts the recoil when firing. The piston case of a marker round being fired in the chamber of the firearm extends its length. This increases the kinetic energy of the floating breech, resulting in the recoil to the back of the weapon and enables the correct operation of the automatic firing mechanism.

The piston case requires conversion of the firearm operating principle; instead of being vented through a lateral vent port in the barrel (which is the most common operating principle of modern assault rifles), the propellant gas must be vented to the floating breech.

2. OVERVIEW OF THE UTM 5.56 MM CALIBRE ROUNDS

A distinguishing characteristic of the MMR (man marker rounds) is the design of the cartridge, which has two separate propellant charges.

The UTM brand cartridge (Fig. 1) has a piston case, comprising an outer slide (4) and an inner body (9) within the former. Inside the inner round is a calibre .22 cartridge rear primer (8), which is a rimfire round. When the rear primer (8) is initiated, its propellant gas propels a ball (7) in the ductway running along the body (9). The ball (7) hits a pistol-type (Boxer) front primer (5) to initiate it and propel the marker projectile through the weapon's barrel. There is an o-ring gasket (6) which provides a seal at the interface of the slide and the body (4 and 9). Once the rear primer has been initiated, the increasing gas pressure propels the ball (7) and extends the body (9) in relation to the slide (4). This kicks back the breech bolt to cycle the automatic mechanism of the firearm. The marker projectile dome (1) is press-fitted inside the forward end of the slide (4) [1]. The cartridge case dimensions match those of the standard NATO intermediate cartridge calibre 5.56×45 mm (SS109); the overall marker cartridge length is shorter than that of the SS109 because of the UTM MMR projectile, which is 53 mm long [2], while the combat live SS109 projectile is 57.4 mm long.

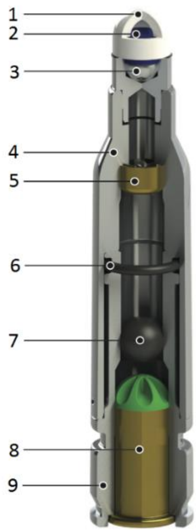

Fig. 1. Cross-sectional view of a UTM MMR cartridge [3]:
1 – dome, 2 – marking compound, 3 – ball, 4 – slide 5 – front primer, 6 – O-ring,
7 – ball, 8 – rear primer, 9 – body

The design of the marker projectile of the UTM MMR (Fig. 2) has the effect of marking the target with the marking compound (3) when it is hit. The marker projectile comprises a hollow body (4), which is the essential part; it guides the marker projectile assembly through the barrel and carries the projectile components.

The body (4) has a diameter lower than the firearm calibre by several hundredth parts of a millimetre and it is not gouged by the barrel grooves; this keeps the barrel interior clean of the projectile body plastic residues. The marking compound (3) is contained within the body (4) with the ball (5) to the back, which, upon physical impact with a target, moves by inertia and squeezes the marking compound (3) out of the body (4). Upon impact with a target, the closing member (2) that contains the marking compound (3) is breached; the marking compound leaves the projectile through the openings of the dome (1). The dome (1) is mounted on the projectile's tip and protects against the breaching and spilling of the marking compound (3) when the round is chambered. [4]

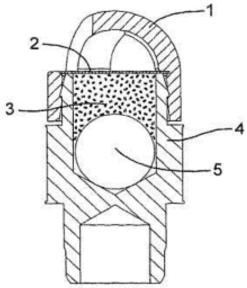

Fig. 2. Cross-sectional view of a UTM MMR cartridge [4]:
1 – dome, 2 – closing member, 3 – marking compound, 4 – body, 5 – ball

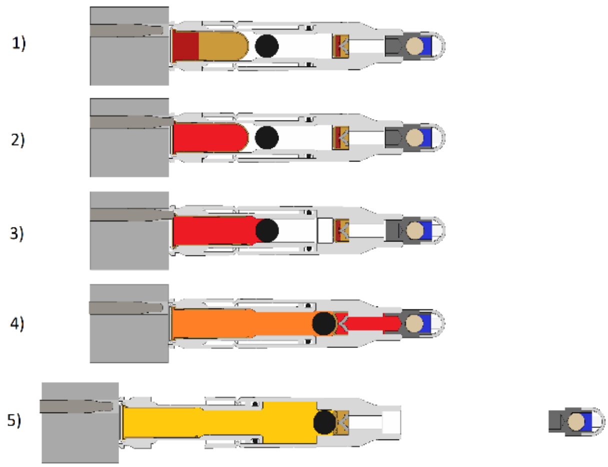

Fig. 3. Firing process of the UTM MMR:
1 – the round is in the chamber; 2 – the rear primer is ignited; 3 – the rear primer neck opens and the ball begins to move; 4 – the ball initiates the front primer, the projectile begins to move while the case body and slide separate; 5 – the case piston cycles the weapon

The diagram in Fig. 3 illustrates the firing process of the UTM MMR. Table 1 shows the tactical performance and technical data with the design, operation and storage specifications of the UTM MMR.

Table 1. UTM MMR ammunition technical characteristics [2]

Tactical performance and technical data	
Cartridge type	5.56 mm UTM MMR
Projectile weight [g]	0.45
Initial projectile velocity [m/s]	122
Initial projectile energy [J]	3.3
Cartridge weight [g]	6
Distance scatter (D100) 10 m [mm]	50
Optimum firing range [m]	30
Maximum effective firing range [m]	50
Maximum range [m]	No data
Noise [dB]	113
Design	
Projectile material	Aluminium or polymeric body and ball; polymeric dome
Marking compound	Non-toxic, easily washable wax-based formula
Marking compound colour	Red or yellow or blue
Case material	Aluminium
Propellant	Front primer initiator
Cap	Boxer pistol cap
Operation	
Operating temperature [^{o}C]	-5 to +40
Firing mode	Single or continuous
Body parts to be protected	Eyes, head, throat, groin
Storage	
Recommended storage conditions	Dry indoor rooms, max. ambient temperature: +40^{o}C
Shelf life	Min. 3 years
Manufacturer's warranty	1 year

Table 2 shows a comparison between the FX, FOF, UTM and live combat ammunition rounds. The approximate projectile muzzle energy of combat ammunition rounds is 1670 J, whereas marker rounds operate at just several joules and are consequently safe for human use. Note that while being the lightest projectile in the comparison, the FX features the highest kinetic energy by virtue of having the highest muzzle velocity of the three round types. The FOF projectile weight is similar to that of the FX; however, the muzzle velocity is much lower, resulting in the lowest kinetic energy of the three round types. The UTM has the smallest scatter, and the FOF has the highest scatter. The FX and FOF design is similar, with a major difference being that the FX cartridge case is brass with a separating plastic sabot; while the FOF rounds feature a slide and a body which separate from one another (and are made from aluminium or aluminium and a polymer). The design of the UTM MMR differs greatly from the preceding round types. The UTM MMR operating principle consists of two separate propellant charges and the ball which intermediates in the energy pulse transmission from the rear primer propellant to the front primer propellant. This increases the cartridge complexity. The FX rounds are the most expensive, while the FOF rounds are the cheapest in comparison. The UTM MMR rounds are between the two in terms of pricing. The advantages of the UTM MMR design include better reliability and the lowest spread out of the three, these factors have made the UTM MMR extremely popular and lend it a competitive edge over rival systems.

Table 2. Comparison of the FX, FOF, UTM and combat ammunition tactical performance and technical characteristics

Projectile type	5.56 mm FX marker projectile round [5]	5.56 mm FOF marker projectile round [6]	5.56 mm UTM MMR [2]	5.56 × 45 mm FMJ steel lead core projectile round (combat grade) [7]
Projectile weight [g]	0.23	0.28	0.45	4.0
Initial projectile velocity [m/s]	300-350	107-152	122	915
Initial projectile energy [J]	5	1.7-3.4	3.3	ok. 1670

3. OVERVIEW OF UTM MMR TRAINING CONVERSION KITS FOR 5.56 MM ASSAULT RIFLES

The purpose of training conversion kits is to allow for firing marker rounds from firearms where the full automatic fire functionality is retained so as to simulate the firearm's component operation with live combat ammunition. A typical training conversion kit includes a breech bolt module; some versions also include round magazines. The training conversion kit manufacturers are trying to minimize the number of interchangeable components as much as possible. Certain training conversion kits come with special training magazines as a safeguard against the accidental loading of combat ammunition. Every conversion kit prevents the unintentional discharge of the firearm with the conversion installed.

There are 5.56 mm UTM MMR training conversion kits available for the following firearm models:

- M16/M4 5.56 mm carbine
- H&K G36 5.56 mm carbine
- Steyr AUG 5.56 mm carbine
- FN SCAR 5.56 mm carbine
- Beretta ARX-160 A1/A2 5.56 mm carbine
- SAR-21 5.56 mm carbine
- Tar-21 Tavor 5.56 mm carbine
- H&K 416 5.56 mm carbine
- SIG Sauer 551/553 5.56 mm carbine
- SIG Sauer 552 5.56 mm carbine
- FNC 5.56 mm carbine
- SA80 IW 5.56 mm carbine
- C7/C8 5.56 mm carbine [8]

Fig. 4 shows the slide and breech bolt assembly (known as the bolt carrier group) of the M16/M4 carbine.

Fig. 4. 5.56 mm breech bolt carrier group (breech and slide) assembly of the M16/M4 carbine [10]

This carbine's operating principle involves venting the propellant gas via a side port in the barrel. The firing action is completed with a closed breech bolt. The barrel is locked by rotating the breech bolt with seven bolts in the bolt chamber seat. The gas chamber is inside the slide. The breech bolt features an extraction, a firing pin, and a case ejector. [9]

Figure 5 shows the breech bolt of a training conversion kit for adapting the M16/M4 carbine for firing the UTM MMR. With the UTM MMR breech bolt installed, the carbine operates on the principle of the floating breech. The breech bolt features the following moving components: the firing pin with a spring, the extractor, the case ejector, and the carrier parts. There is no gas chamber in this assembly. The firing action is completed with a closed breech bolt. There are two sending noses that are interfaced with the case bottom when the round is stripped from the magazine and fed into the chamber; both sending noses are designed just like the two bottom bolts of a standard breech bolt. The blue mark is visible through the case ejector port when the conversion kit is installed in the firearm to indicate that the weapon has been converted for firing the UTM MMR.

Fig. 5. UTM conversion breech bolt for the M16/M4 5.56 mm carbine [10]

The M16/M4 carbine has the firing pin aligned with the breech bolt centreline (Fig. 6(a)). The live combat rounds for this firearm are centre-fire rounds with a dia. 4.475 mm cap. The UTM rounds are rimfire rounds with a dia. 6.9 mm cap. The training conversion kit firing pin is offset by 3 mm from the standard breech bolt firing pin position (Fig. 6 (b) and (c)). The firing pin offset prevents the discharge of a live combat round, since the conversion firing pin slams the live round case bottom, missing its cap (Fig. 6 (c)). The firing pin spring is prevented from slamming into the cap by inertia when a round is fed into the chamber or whenever the firearm falls onto a hard surface.

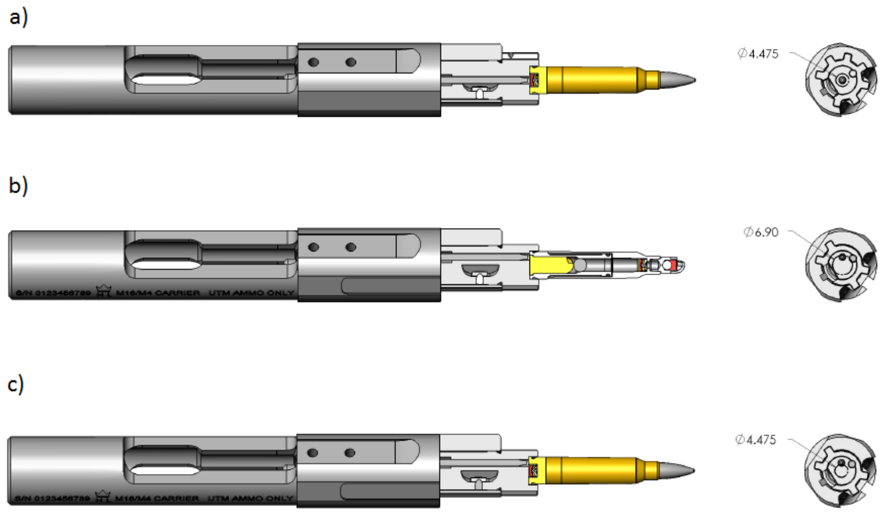

Fig. 6. Position of the round relative to the breech bolt [11]: (a) live combat round with a standard breech bolt; (b) the UTM round with the conversion breech bolt; (c) live combat round with the conversion breech bolt

Figure 7 shows the bottom of a live combat round after an attempt to discharge the converted firearm. The green arrow shows the firing pin impact mark.

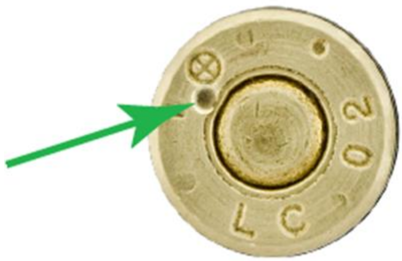

Fig. 7. 5.56 × 45 mm live round with a firing pin mark from the UTM conversion kit [10]

The UTM conversion kit is designed to operate with the MMR (Man Marking Rounds) and the UTM BBR (Battlefield Blank Rounds), which are mock rounds. The fail-safes of the UTM conversion kit prevent the accidental discharge of the UTM TBR (Target Bullet Rounds). The TBR feature plastic-jacket aluminium core projectiles, with a maximum initial energy of 15 J. The TBR are not intended for human marking, their design ensures a low risk of rebound, and no TBR should pierce the target sheet. The TBR has a different UTM training conversion kit.

The difference is as follows: the UTM conversion firing pin moves out of the breech bolt front by 1 mm (Fig. 8), igniting an MMR or BBR cap; the UTM TBR dedicated conversion kit has the firing pin extending by 2.1 mm (Fig. 2.2 (b)). Hence, the very design of the TBR prevents the initiation of its cap with the 1 mm travel firing pin (the firing pin does not touch the TBR cap), as shown in Fig. 9.

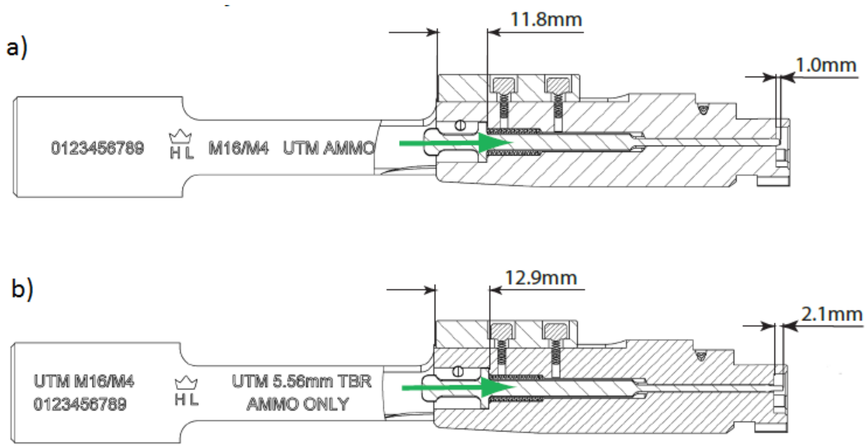

Fig. 8. (a) UTM MMR breech bolt; (b) UTM TBR breech bolt [11]

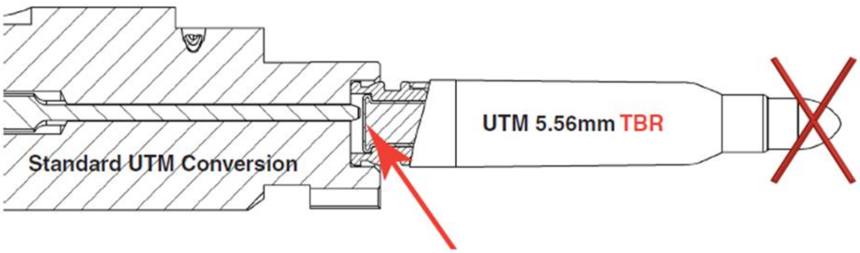

Fig. 9. (a) UTM conversion kit and its firing pin's effect on the UTM TBR [11]

Firing a UTM round fed from live combat 5.56 × 45 mm standard magazines is possible and legal. However, it is recommended to use polymer-made training conversion kit magazines in blue (Fig. 10) which prevent the loading of live combat ammunition due to the smaller inner chamber length. The UTM rounds are 53 mm long and fit into the training conversion kit magazines, while the live combat rounds are too long (at 57.4 mm). Using UTM magazines improves operational safety, and their blue colour shows the firearm operator that the magazine is a part of the training conversion kit.

It is also more reliable in operation with UTM rounds: the magazine feeding follower is inclined 3^{o} relative to the barrel centreline, which reduces the likelihood of damaging the MMR, and improves the reliability of feeding the chamber [12].

Fig. 10. UTM “Blue” Safety Magazines for M16/M4 assault rifle

4. CONCEPT DESIGN OF THE TRAINING CONVERSION KIT

The Polish MSBS-5.56 assault rifle (MSBS – Modular Short Firearm System) operates by venting a portion of the propellant gas through a side vent port in the barrel. With the training conversion kit, the MSBS-5.56 assault rifle will work on the principle of the floating chamber. Figure 11 shows the breech bolt and slide assembly of the MSBS-5.56 assault rifle.

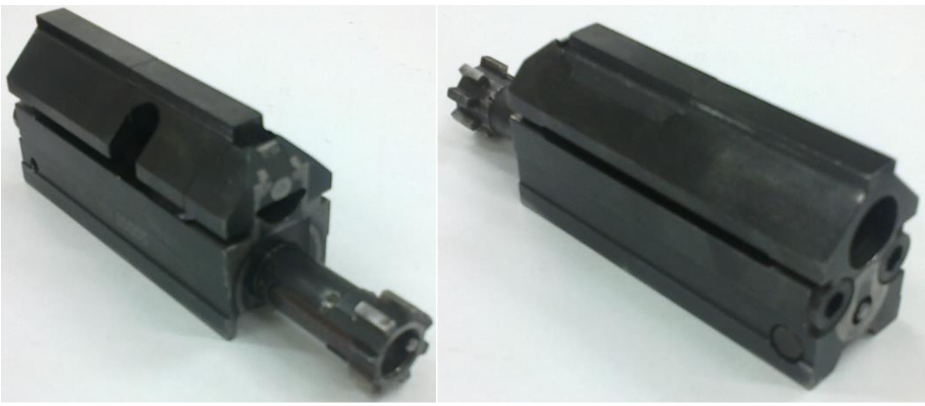

Fig. 11. Breech bolt carrier group (breech and slide) assembly of the MSBS-5.56 assault rifle

The firing action is completed with a closed breech bolt. The breech is locked with six bolts. The breech bolt features an ejector, a case extractor, and a firing pin. Thus, the training conversion kit should feature the same components.

A UTM training conversion kit (Fig. 12) for the MSBS-5.56 may be manufactured by adapting the typical components of the firearm to the specifications of the UTM system.

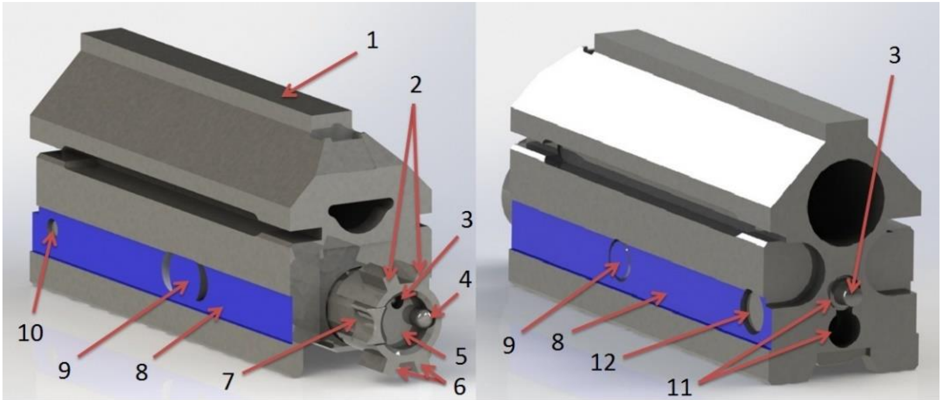

Fig. 12. Concept model of the UTM training conversion kit for the MSBS-5.56 assault rifle:
1 – bolt carrier; 2 – sending noses; 3 – firing pin; 4 – extractor; 5 – head bolt; 6 – sending noses; 7 – ejector; 8 – mark; 9 – pin; 10 – retaining pin hole; 11 – firing pin holes; 12 – firing pin retaining pin

The bolt carrier (1) is based on the slide design, whereas the head bolt (5) is based on the breech bolt of the standard-issue MSBS-5.56 assault rifle. The head bolt (5) is reversible to the sides by 180^{o} once its pin (9) has been removed to adapt the UTM training conversion kit for either left or right-side case ejection. The firing pin hole in the head bolt (5) needs to be offset eccentrically by 3 mm from the original centreline alignment. The bolt carrier (1) needs to have two holes (11) manufactured for the firing pin (3) installation depending on the case ejection side, and another hole (10) for the firing pin (3) retaining pin (12). The firing pin (3) should be fabricated with its spring so that its tip extends out of the breech bolt head by 1 mm. Two sending noses (6) are present in the training conversion kit to strip the round from the magazine in the right-side case ejection configuration, and two other sending noses (2) with the same function are provided for the left-side case ejection. These sending noses are counterpart to the bolts in the standard-issue breech bolt and share the same design. The ejector (4) is the same as in the standard-issue version of the firearm.

The case extractor (7) has been modified to accommodate the offset firing pin (3) in the training conversion kit. The blue mark (8) is placed on both sides of the bolt carrier (1) and shows that the firearm has been converted to fire with training rounds. It will be visible through the case ejector port in both forms of ejection configurations (Fig. 13).

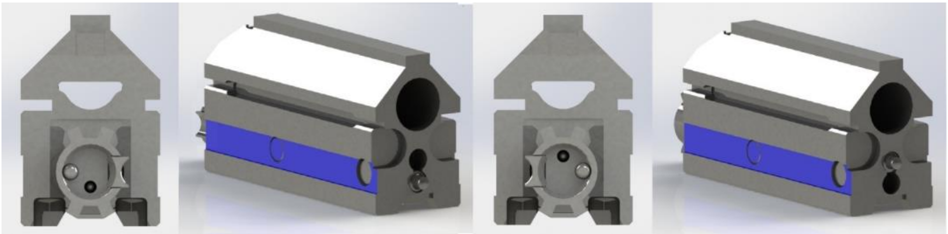

Fig. 13. Conversion kit breech bolt with the left-side case ejection (see left) and the right-side case ejection (see right)

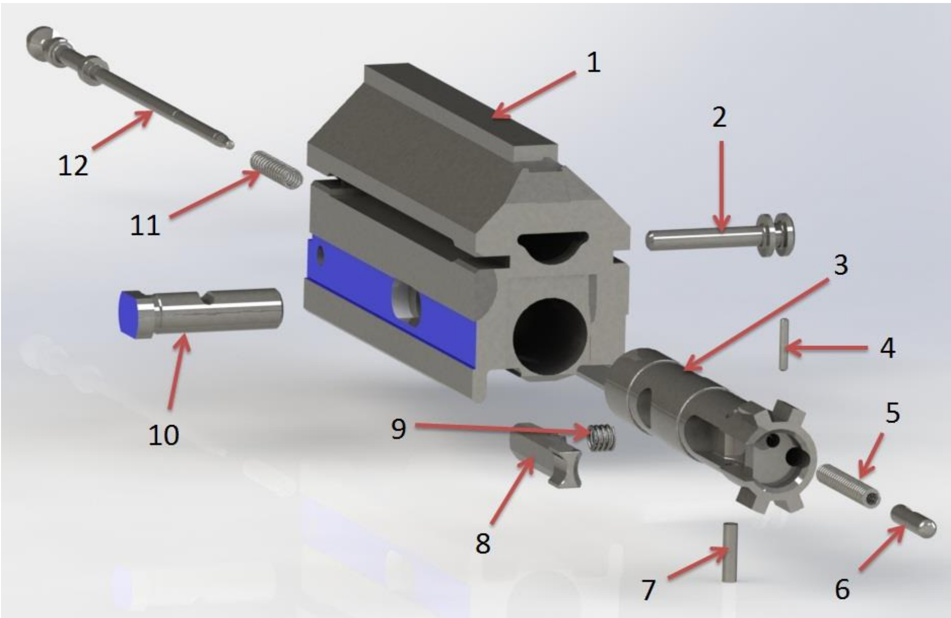

Fig. 14. UTM conversion breech bolt components for the MSBS-5.56 assault rifle: 1 ─ bolt carrier; 2 ─ firing pin retaining pin; 3 ─ head bolt; 4 ─ ejector pin; 5 ─ ejector spring; 6 ─ ejector; 7 ─ extractor pin; 8 ─ extractor; 9 ─ extractor spring; 10 ─ pin; 11 ─ firing pin spring; 12 ─ firing pin

The fail-safe (Fig. 15) that prevents firing live combat rounds from the converted firearm consists of the eccentric offset of the firing pin by 3 mm (3). The extension of the firing pin tip by 1 mm (2) from the breech bolt head prevents firing with the UTM TBR. A second fail-safe of the training conversion kit is the firing pin spring (1) which prevents the discharge of the firearm through firing pin inertia when a round is fed into the chamber or whenever the firearm falls onto a hard surface.

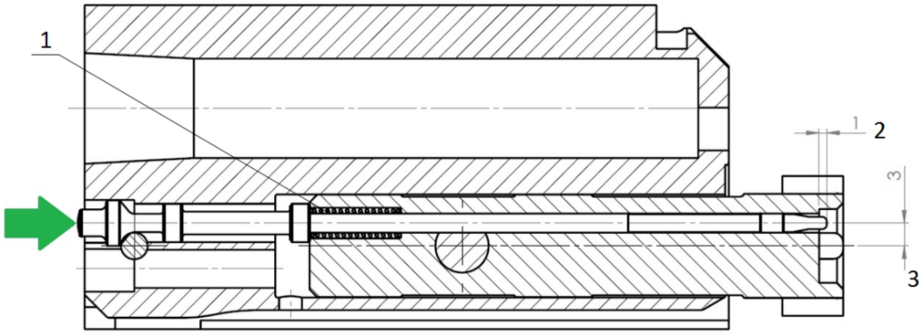

Fig. 15. Fail-safe structural features of the UTM conversion breech bolt for the MSBS 5.56 assault rifle:

1 – firing pin spring; 2 – 1-mm firing pin extension from the breech bolt head; 3 – 3-mm eccentric offset of the firing pin

5. CONCLUSION

UTM brand ammunition is a modern solution for training rounds intended for the effective training of law enforcement and military operators in very life-like combat situations and with a high level of safety standards for users. It is very much recommended to consider the issue of UTM training conversion kits with the latest standard-issue short firearm of the Polish Army, the MSBS 5.56 assault rifle.

The completed analysis of the state of the art and the developed design shown herein may well serve the implementation of a UTM solution for this firearm type. The system provides fail-safe standards which are as good as the UTM counterparts for other assault rifles and carbines, it should retain the semi-automatic operation of the firearm.

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Koncepcja zestawu treningowego na nabój UTM MMR do karabinka MSBS-5,56

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Streszczenie. W artykule przedstawiono przegląd stanu techniki amunicji ćwiczebnej barwiącej 5,56 mm UTM MMR (Ultimate Training Munitions Man Marker Round), w którym opisano jej budowę oraz zasadę działania. Zawarto również przegląd zestawów treningowych na nabój UTM przystosowujących karabinki kalibru 5,56 mm do strzelania niniejszą amunicją, opisano ich budowę, zasadę działania i zastosowane rozwiązania zapewniające bezpieczeństwo. Na podstawie przeprowadzonych analiz opracowano i opisano koncepcję zestawu treningowego na nabój UTM MMR do karabinka MSBS-5,56.
Słowa kluczowe: broń strzelecka, karabinek, amunicja ćwiczebna barwiąca, zestaw treningowy