



Delayed Blowback Operation Firearms in the Small Arms Classification

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Abstract. This paper presents the general principle of operation of delayed blowback small arms, their classification by the applied blowback delay, and a discussion of the existing designs. An analysis was carried out to rate the specific design solutions. The results of this work will be used in further investigations into and testing of delayed blowback firearms.

Keywords: mechanical engineering, small arms, firearm design, classification, delayed blowback

1. INTRODUCTION

A firearm is a specific heat engine which utilises the energy of the gases formed by violent combustion of a propellant to endow a projectile with kinetic energy. One of firearm type is the automatic firearm, in which all actions during a shot cycle (save for chambering the first round and pulling of the trigger) are done without any intervention of the shooter and driven by the energy of the propellant gases. Automatic firearms can be classified by how the energy is applied, or by their 'operation', and this classification includes gas operated small arms, recoil operated small arms (in which the barrel or the breech or the whole weapon recoils): blowback operated small arms (in which with simple blowback and delayed blowback), short/long recoil operated small arms (with barrel recoiling on short/long distance), inertia operated small arms and blow-forward operated small arms [1]. The most popular firearm operation (or design) types include gas operated (GO), (short/long) recoil operated (RO) and blowback (simple and delayed) operated (SBO, DBO).

Continuous technological progress and incessant changes in the specifics of warfare require modification and upgrading of small arms. Some problems exist which are largely disregarded or not understood as worthy of utilizing their potential to the fullest. Many literature references concerning firearms focus mainly on gas operated small arms. Few generally available publications exist which detail delayed blowback operation firearms [2]. It is the purpose of this paper to attempt a classification of DBO firearms, an analysis of DBO design solutions, and indicate which solutions may be suitable for future improvement.

2. CLASSIFICATION OF DBO SMALL ARMS

Delayed blowback operation is a certain evolution of the simple blowback operation. In a SBO firearm, the barrel remains stationary and not locked with the bolt. The breech is closed by the force of inertia of a bolt of sufficient weight and supported by a recoil spring. The operation cycle of a small arm is triggered by the propellant gas pressure applied to the case base and further to the breech face, by which the cycle begins simultaneously with the movement of the bullet inside the barrel. During the recoil, the bolt compresses the recoil spring by which the latter accumulates energy. Having reached its limit of backward movement, the bolt returns forward by the release of the recoil spring, while actuating the reloading cycle and ultimately closing the breech. An undisputed advantage of SBO small arms is their simple design. However, this solution has certain restrictions on the viable ammunition types since only cartridges with relatively low muzzle energy projectiles can be used (and largely limited to pistol cartridges).

Any ammunition with a higher kinetic energy of the bullet requires a heavier bolt or a stiffer recoil spring, one effect of which is an increase in the weight and recoil of the small arm, coupled with a wider spread of projectiles [1, 3].

To minimise these drawbacks and to retain the maximum number of advantages of SBO, design solutions were created which can be operated with intermediate and rifle cartridges. The main difference which separates DBO small arms from SBO small arms is that the former features additional components or mechanisms which further decelerate the bolt recoil in its first stage of movement (when the propellant gas pressure is the highest). This delay effect in opening of the bolt is achieved by the addition of a decelerating force, an apparent increase in the bolt weight, or a combination of them. When the delayed bolt movement ends, the automatic action progresses like in SBO small arms [1, 4].

Some designs, especially old ones, featured relatively straightforward solutions with a single-component bolt. Many solutions featured a two-component breechblock comprising a bolt head, which is a front component that directly mates the cartridge/case and closes the breech; the bolt carrier is coupled to a bolt head, forming the rear component of the two, usually heavier than the bolt head. When a round is fired, the bolt head moves slightly, which corresponds to a much longer travel of the bolt carrier (which means a ratio > 1). Once the bolt carrier is powered, the delayed blowback ends and both bolt components move together at the same speed.

The case is extracted under high pressure, which is usually alleviated with Revelli grooves in the chamber; earlier designs required solving this issue by oiling the cartridge cases. In designs with Revelli grooves, the propellant gases during a shot enter the space between the case and the chamber and thus the pressure is equalized (on both sides of the case wall); this action reduces friction, facilitating case extraction with a lower risk of case failure and breakage. Figure 1 shows the layout of Revelli grooves in the chamber of a HK P7 pistol (there are 17 channels spaced every 20° , with a 40° interspace where the gas port is) [5].

The DBO small arms are classified by the method of delay into gas DBO, friction DBO, and mechanical DBO (Fig. 2). Gas DBO designs can include solutions with or without a gas piston. Friction DBO designs can include a solution based on the friction of the bolt or its components against purposefully-shaped receiver surfaces or on the friction of the case against the chamber, providing an effect with the action opposite to that provided by Revelli grooves.

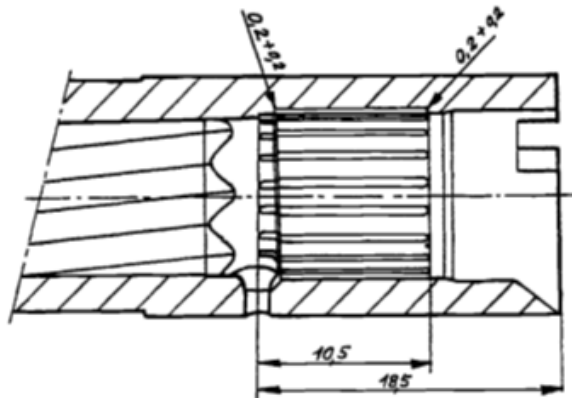


Fig. 1. Fluted barrel chamber of a HK P7 pistol [5]

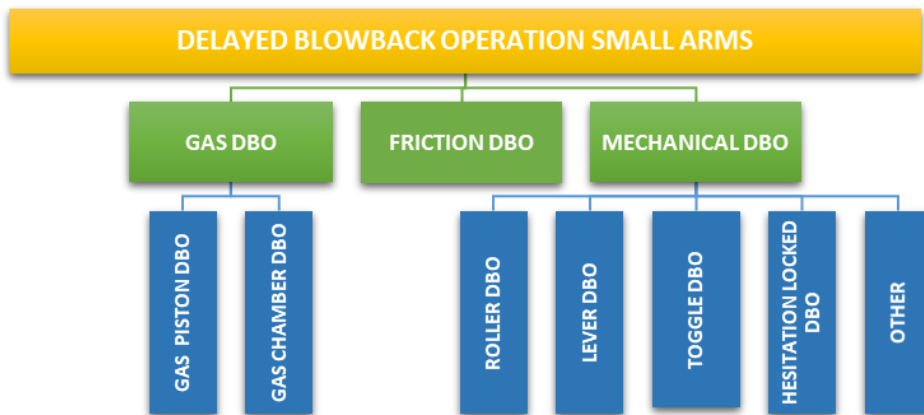


Fig. 2. Classification of DBO small arms

Mechanical DBO small arms vary in the design solutions which increase the breechblock inertia to delay its opening. Unlike the designs of weapons with locked breech which require unlocking by the motion of a separate component (like the slide or the bolt carrier), DBO small arms are called ‘half-locked system’ firearms. The bolt can be automatically unlocked by inclining the respective mating surfaces at an angle which is higher than the angle of friction. Similar to SBO designs, in DBO designs the bolt moves slightly to the rear while the projectile travels through the barrel; the backward travel of the bolt is a distance which allows compliance with the so-called safety condition (and the distance is no longer than the thickness of the case bottom).

3. OVERVIEW OF DBO SMALL ARM SOLUTIONS

3.1. Gas DBO small arms

Unlike in GO firearms, in gas DBO firearms the energy of part of the propellant gas is applied to delay the motion of the bolt/slide, especially to delay its opening when a shot is fired. In most gas DBO design solutions, the part of the barrel directly ahead of the chamber features a gas port which opens to the gas chamber (usually below the barrel) which is open to the front and not to the back, as in GO firearms (Fig. 3). A gas piston connected to the front part of the slide is found inside of the gas chamber. When a round is fired, the bolt/slide is recoiled under the propellant gas pressure applied to the case bottom and at the same time its movement is delayed by the gases pressing against the gas piston. When the projectile clears the barrel, the gas chamber and barrel gas pressure falls to a value at which the recoil force exceeds the force of the delaying gas, and so the bolt/slide opens [6, 7].

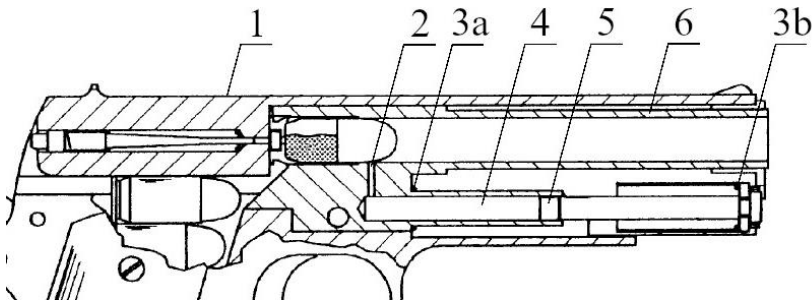


Fig. 3. Gas piston DBO: 1 – slide; 2 – gas port; 3a, 3b – start and end of the recoil spring; 4 – gas chamber; 5 – gas piston; 6 – barrel (fig. based on [8])

One of the most popular gas piston DBO pistols is the 9 mm HK P7. Similar solutions were used in other 9 mm pistols: the Chinese Norinco Model 77B, the South African ADP Mk II, the Czech Kevin ZP98, the Bulgarian Arsenal P-M02, and the German Walther CCP. The 9 mm Laugo Arms Alien made in 2019 has a slightly different design by which the gas chamber with the piston is over the barrel [9].

A much less popular solution is the gas chamber DBO first used in the German 7.92 mm Volkssturmgewehr VG 1-5 carbine and modified later for the 9 mm Steyr GB pistol designed in 1974 (Fig. 4). A part of the propellant gas escapes through the gas ports in the barrel and flows to the gas chamber formed by the cylinder. The gas ports were located too far from the chamber and too closed to the muzzle which made the delayed blowback operation rather ineffective, and the slide was relatively heavy [10].

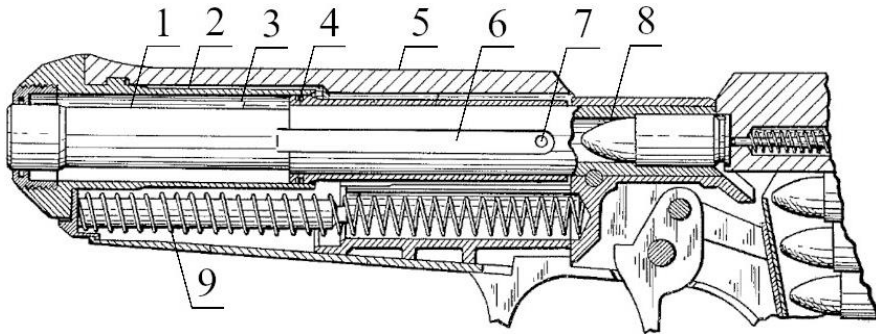


Fig. 4. Gas chamber DBO: 1 – barrel; 2 – cylinder; 3 – gas chamber; 4 – rim/piston; 5 – slide; 6 – gas channel; 7 – gas port; 8 – chamber; 9 – recoil spring
(fig. based on [11])

3.2. Friction DBO small arms

Friction DBO small arms have the bolt motion and opening delayed with a carefully generated friction of the bolt (or its parts) against the oblique surfaces inside the receiver or the friction of the case against the chamber walls.

In this class is the popular 20th century design, the Thompson M1921 and M1928 11.43 mm calibre submachine guns, in which DBO was based on the so-called Blish lock effect by which the coefficient of friction of two mating parts loaded with different forces was changed. The Blish lock effect was achieved by careful selection of structural materials and the inclination angle of the abutment surfaces [12]. The construction of the actual weapon was much more complicated; the slanted recess of the bolt featured an H-shaped insert (made of bronze) with side bosses, and the lengthwise recess featured an opening insert (complete with a cocking handle). The side bosses of the bronze H-shaped insert mated with the slanted abutments of the receiver and the cross-wise link mated with the recess of the insert. During the high pressure action in the barrel, the friction of the insert against the bolt prevented the former from being displaced upwards, holding the side bosses behind the receiver abutments. Once the action of high pressure was gone, the insert would lift and release the bolt. The bolt insert weight was negligible to the blowback delay, especially in the original version of the Thompson SMG (M1921). Note that the design engineers at Auto Ordnance repeatedly tried and failed to make a working firearm with the Blish lock and fed with a different type of ammunition. During World War 2 the Thompson SMG was simplified by replacing the complicated DBO with a sufficiently heavier SBO bolt. Another seemingly simple DBO solution is to increase the friction of the case against the chamber walls. This friction is naturally present in SBO, and requires special caution with cartridges with high muzzle energy projectile by lubricating them with oil, as was the case with Oerlikon automatic anti-aircraft guns.

The first known friction DBO small arm was the Mann Model 1920/21 6.35 mm pistol. Designed by Fritz Mann, it was not significantly different from any SBO 'pocket pistol'. In the middle part of the chamber there was an annular recess and the chamber entry was tapered (Fig. 5). Then the propellant gas pressure acted on the case, which caused bulging and plastic deformation. The friction of the bulging case drawn through the recess of the chamber caused the delayed blowback operation [13]. Correct operation of this design solution depends on the quality of the ammunition and the properties of the structural materials. The same friction DBO can be found in the LWS-32 Seccamp 7.65 mm pistol and the Type 77 7.65 mm pistol. The annular recess is sometimes replaced by spiral grooves which resembled rifling, as used in the Type 64 7.65 mm pistol [5].

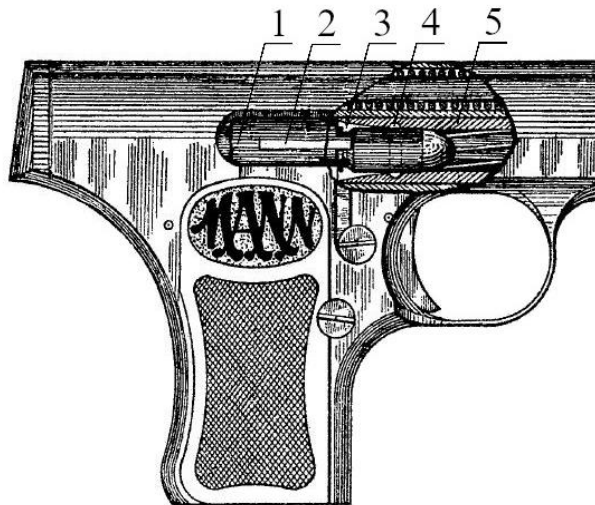


Fig. 5. Friction DBO in the Mann pistol: 1 – bolt; 2 – extractor; 3 – chamber; 4 – annular groove; 5 – barrel (fig. based on [14])

3.3. Roller DBO small arms

A roller DBO design was achieved by simplification of roller locked firearms, where the rollers moved outwards as the bolt was locked. During World War 2, the MG 42 short recoil roller-locked machine gun entered service in the Third Reich. The design was simplified in 1944, resulting in a prototype design designated MG 45 which featured roller DBO. At the same time a successor of the MP 43/44 (StG44) assault rifle was sought and Mauser developed a prototype called Gerät 06, a gas-operated roller-locking firearm. It evolved into Gerät 06(H), a roller DBO assault rifle designated StG45. Later on, the designers of this small arm created the CETME Modelo 58 (CETME Model B) battle rifle in Spain.

It was the engineering launchpad for what later became one of the most popular rifles ever, the HK G3 (7.62 × 51 mm NATO cartridge-fed), manufactured from 1959 [15].

In roller DBO designs, the bolt head was connected with the bolt carrier via a breech block insert (called the “control member”), which housed the firing pin (Fig. 6). The front section of the breech block insert featured tapered surfaces which mated with two rollers (which were regular and cylindrical) symmetrically arranged in the recesses of the bolt head. Before a round is fired, the rollers are retracted outward and partially engage the recesses in the barrel housing, while resting on the retaining surfaces. When a round is fired, the propellant gas pressure is applied via the cartridge case bottom and onto the breech face. The bolt head can start its reverse motion once it overcomes the resistance of the rollers. The rollers go over the tapered surface of the barrel housing while pressing against the tapered surface of the breech block insert, retracting the latter with the bolt carrier. This provides a ratio higher than one, where a small travel of the bolt head forces a longer travel of the bolt carrier. When the rollers are finally pushed out of the barrel housing and retracted back into the bolt head, the whole breechblock assembly is moved further. Many designs of this kind are complemented by an anti-bounce lever placed into the bolt carrier to prevent ‘bounce back’ of the breechblock once it returns forward. When the breechblock is forward, the end of the anti-bounce lever engages a lug on the bolt head. Once a shot cycle is complete, the anti-bounce lever disengages the lug, to rest against the bolt head. In the return motion, when the rollers return in the recesses on the barrel housing, the anti-bounce lever catches the bolt head lug. Sometimes the anti-bounce lever is replaced with an anti-bounce mass formed by tungsten granules. It fills a part of a hollow inside the bolt carrier and moves with it; the inertia of the anti-bounce mass prevents the bounce of the breechblock [15, 16].

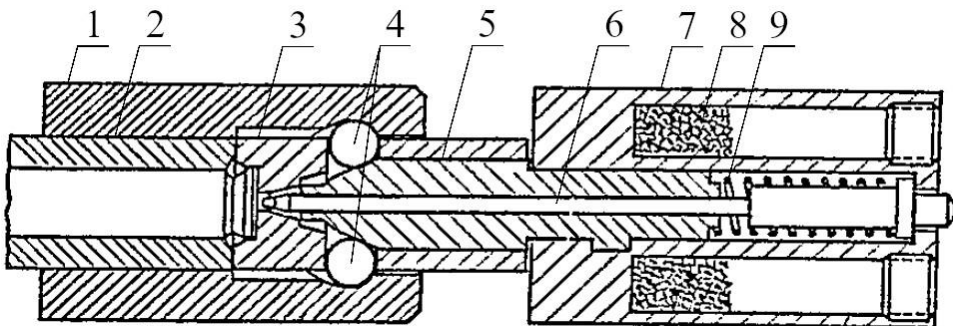


Fig. 6. Roller DBO: 1 – barrel housing; 2 – barrel; 3 – bolt head; 4 – rollers; 5 – control member; 6 – firing pin; 7 – bolt carrier; 8 – anti-bounce mass; 9 – firing pin spring (fig. based on [17])

The design solution applied in the HK G3 rifle became the calling card of many designs from Heckler & Koch, including the HK P9 9 mm pistol, the HK MP5 9 mm SMG, the HK33 and G41 5.56 mm assault rifles, the HK21 7.62 mm MG, and the MSG90 and PSG1 7.62 mm sniper rifles. Roller DBO systems similar to those applied in HK small arms were also used in the U.S.-made Calico M960 9 mm SMG, the Swiss SIG SG-510 (StG 57) 7.5 mm battle rifle, and the SIG MG 710-3 7.62 mm machine gun [15,16].

3.4. Lever DBO small arms

An apparent increase of the breechblock mass can also be accomplished by applying a lever which separates the front and rear parts of the bolt (Fig. 7). It is usual for lever DBO designs to feature the lever mounted on a pivot of the bolt head and with the long arm of the lever engaging the bolt carrier while the short arm rests on the receiver abutment. When a round is fired, the case bottom presses against the bolt head, which must overcome the resistance of the supported lever to rotate it and drive the bolt carrier to achieve blowback operation. With the bolt carrier in motion and the lever rotated (to a position where it no longer rests on the receiver abutment), both parts of the breechblock move further like in a SBO firearm [16].

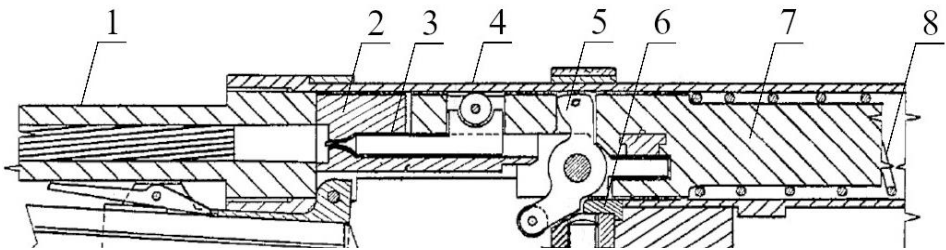


Fig. 7. Lever DBO: 1 – barrel; 2 – bolt head; 3 – firing pin; 4 – receiver; 5 – lever; 6 – receiver abutment; 7 – bolt carrier; 8 – recoil spring (fig. based on [18])

The lever DBO solution was first patented by Paul Kiraly in 1913 [19]. Based on his patent, he designed a 9 mm SMG called Danuvia 39M (followed by 43M and 44M) and the San Cristobal Model 1 and 2 7.62 mm carbines [20, 21]. The DBO is rarely found in machine guns, but it is the operation type of the French-made MAS AA-52 7.5x54 mm MG, introduced in the 1950s and still in service [16]. In the 1960s, a 5.56 mm bullpup assault rifle was developed under the name FAMAS, one of the most popular DBO small arms. It was only several years ago that the French Armed Forces began replacing the FAMAS with a new solution [22].

Lever DBO is also used in PDWs (personal defence weapons), like the ST Kinetics CPW 9 mm SMG designed in 2008. Its structure is made of heavy-duty lightweight materials (including polymers and aluminium alloys), and coupled with the DBO, the SMG weighs only 1.7 kg and provides a theoretical rate of fire more than 900/min [23].

3.5. Toggle DBO small arms

One of the first concepts for mechanical DBO to be implemented on a large scale originates from the beginning of the 20th century. The German engineer Andreas Schwarzlose successfully applied a toggle DBO in his M.7 8 mm machine gun (Fig. 8) [24]. Its massive firing pin was ended with a disk supported by a recoil spring. The bolt was linked to the receiver by two rotating levers. When projectile was fired, the bolt needed to turn the levers from a position (near dead centre) which caused a considerably delayed blowback in the first stage of the firing cycle.

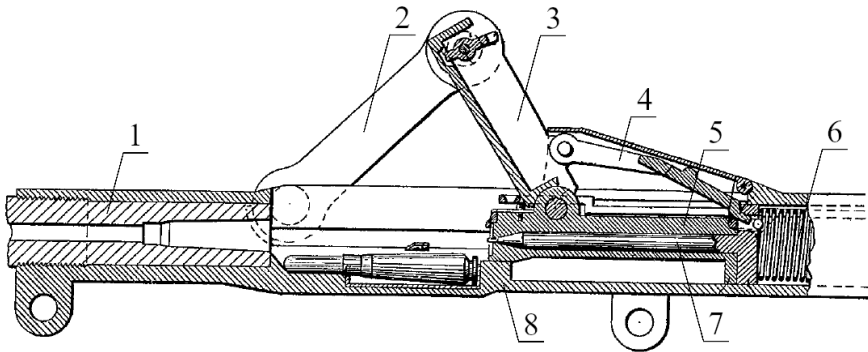


Fig. 8. Toggle DBO in the Schwarzlose machine gun: 1 – barrel; 2 – external lever; 3 – internal lever; 4 – trigger lever; 5 – bolt; 6 – recoil spring; 7 – firing pin; 8 – receiver (fig. based on [24])

To minimise the risk of breaking a case and to facilitate its extraction from the chamber when firing the Schwarzlose machine gun, the receiver cover features an automatic oil pump which thinly lubricated case of every cartridge rammed to the chamber. The Schwarzlose MG had the shortest barrel of all machine guns of its time, measuring 530 mm only, by which bullets left the muzzle faster and the bolt could open sooner due to a faster depressurization of the barrel, resulting in a high fire rate. Unfortunately, thanks to this both the muzzle velocity and range suffered. In its day, the Schwarzlose MG was relatively light, featured few components and was easy to disassemble [25].

A similar DBO design was patented by John Pedersen (Fig. 9), who implemented a different method to facilitate the case extraction in his rifle – the cases were factory-coated with wax. Despite the simple construction, the Pedersen rifle only reached the prototype stage.

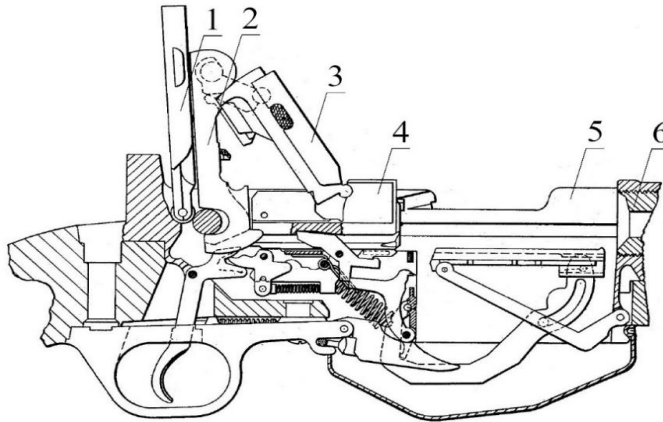


Fig. 9. Toggle DBO in the Pedersen rifle: 1 – bolt carrier; 2 – crank; 3 – connecting rod; 4 – bolt head; 5 – receiver; 6 – barrel (fig. based on [26])

3.6. Hesitation locked DBO

In the first days of World War 2, Eugene Reising designed the Reising M50 submachine gun, which was a weapon far less expensive than the competing Thompson SMG. Following its poor *début* during the Pacific War, the Reising M50 had long service among U.S. security operatives. In his SMG, Reising implemented a hesitation locked DBO system where the bolt rested on the abutment surface of the receiver (Fig. 10). This surface is inclined at an angle higher than the angle of friction which resulted in DBO.

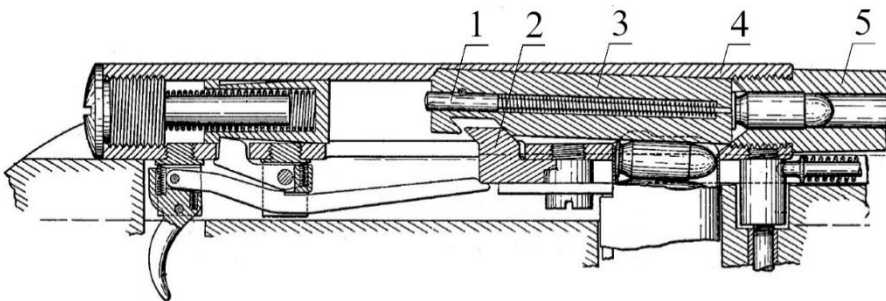


Fig. 10. Hesitation locked DBO in the Reising M50 submachine gun: 1 – firing pin; 2 – action bar; 3 – bolt; 4 – receiver; 5 – barrel (fig. based on [27])

Before World War 1, John Pedersen designed the Remington Model 51 9 mm pistol with a hesitation locked DBO. The breechblock featured a slide and a bolt head located inside of the former. Once a round is fired, the whole breechblock start moving to the rear by the action of the propelled gas on the case. The bolt head travels for approximately 2 mm, its rear arm meets the frame, and stops. The slide continues to move back and after approx. 5 mm its oblique face acts on the bolt head to raise the rear end of the latter by which the top lug of the bolt head engages with the recess in the slide. By this time the pressure of propellant gas in the barrel has been reduced to a safe level and both parts of the breechblock continue moving to the rear. A specific feature of this design from Pedersen is that the abutment surfaces of the bolt head and the frame are aligned at an angle smaller than the angle of friction (and to unlock the bolt head the slide must move), while before a round is fired the bolt head does not rest against the abutment surface of the frame. In this way the bolt head propels the slide strikingly (with a relatively short distance of travel) and strikes the frame afterwards. The bolt head remains stationary in this position until it is raised.

The same solution was used in other Remington pistols: Model 53 and R51 (the latter designed in 2014 and fed with 9×19 mm Parabellum cartridges); a slightly modified version of this hesitation locked DBO solution was used in the Swiss SIG MKMS 7.65 mm SMG (where the bolt head was lowered during recoil instead of raised) [28].

3.7. Other solutions of DBO small arms

In the first days of automatic small arms development, relatively simple DBO solutions were used, like one-component bolts with locking lugs inclined at angles much higher than the angle of friction. Such a solution for a semi-automatic rifle was patented in 1904 by Ferdinand von Mannlicher [29]. The design never evolved past the prototype stage due to the cartridge type and an unsolved issue with case extraction. A similar DBO solution was sought later and without success by engineers from Auto Ordnance. The designs of Abiel B. Revielli from World War 1 deserve honourable mention: the Villar-Perosa Mod. 15 submachine gun and the SIA Mod. 18 machine gun [30]. Both were DBO designs which had one-component bolt with a single locking lug which engages the locking surface, inclined at 45° . In the first stage of blowback operation, the bolt moves to the rear while rotating and delaying its opening.

Another rarely used DBO solution is the rotating barrel DBO design implemented in the Savage Model 1907 7.65 mm pistol and the MAB PA-15 and QSZ92-5,8 9 mm pistols. By this design, the barrel lug engages the guiding groove inside the slide. Firing a round generates a force where the blown back slide rotates the barrel, and this force is opposed by a force generated by the action of the projectile on the barrel grooves and the inertia of the barrel, and this continues until the bullet clears the barrel [16, 31, 32].

An interesting and reasonable DBO solution was applied in the FN Five-sevenN and Ruger-57 pistols (Fig. 11) [33]. Each of the pistols features a single-component bolt (slide) and a moving barrel; the two parts are separated by a lever rotating in the vertical plane and located inside the frame below the barrel. The short arm of the lever rests on the front surface of the barrel lug, while the long arms of the lever engage the grooves in the side walls of the slide. The geometry of this system was designed so that when blown back by the energy of the shot, the slide presses against the long arms which in turn rotate, while the short arm presses against the barrel and retracts it. Like so, until the long arms leave the slide grooves, the barrel increased the inertia of the slide.

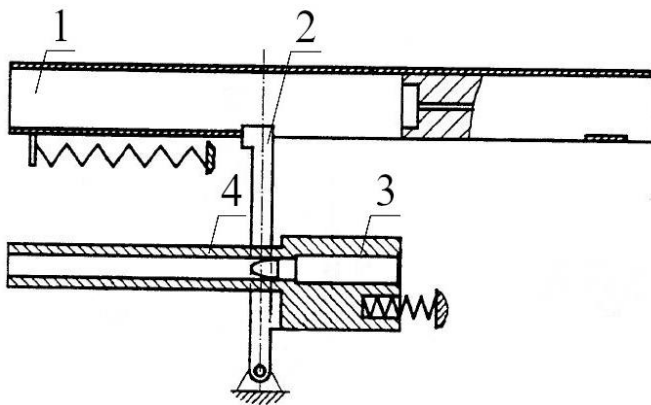


Fig. 11. DBO in the FN Five-sevenN pistol: 1 – slide; 2 – lever; 3 – chamber; 4 – barrel (fig. based on [33])

One of the newer DBO systems is called radial DBO (Fig. 12) and implemented in a U.S. 11.43 mm submachine gun, the CMMG Mk 45 Guard designed off the AR-15 rifle in 2017. The DBO is achieved as a consequence of the necessary rotation of the bolt head, which is forced by mating of its slanted lugs with the abutments on the barrel housing. When a round is fired, the bolt head rotates and moves slightly backward, acting on the guide cam and forces acceleration of the bolt carrier backward. When the bolt head achieves a rotational angle at which its lugs clear the abutments of the barrel housing, the whole breechblock starts the simple blowback operation [34]. The solution seems to be difficult in terms manufacturability.

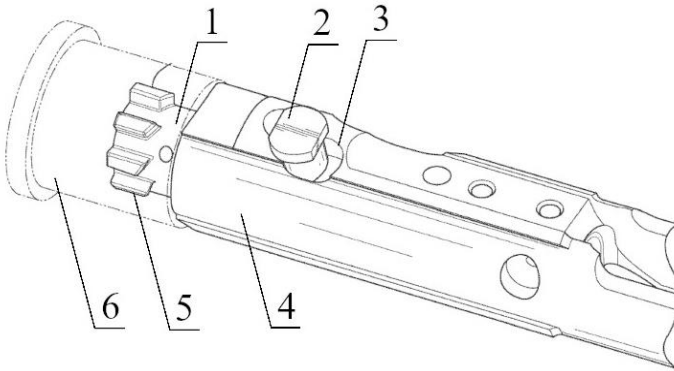


Fig. 12. Radial DBO in the CMMG Mk 45 Guard submachine gun: 1 – bolt head; 2 – cam pin; 3 – guide cam; 4 – bolt carrier; 5 – bolt lugs; 6 – barrel housing (fig. based on [34])

Another U.S. made submachine gun is the Kriss Vector, which features a two-component breechblock (both parts connected by a joint), the recoil energy of which is diverted by a guide cam downward and onto the recoil spring installed along the handgrip (Fig. 13). The special shape of the guide cam causes the bolt head to retract a little in the first stage of a shot, while the bolt carrier begins to descend. Next the bolt carrier pulls the bolt head with it, lowering the rear end of the latter. The downward motion of the bolt head allowed a reduction in the firearm's length and reduced the barrel jump [35].

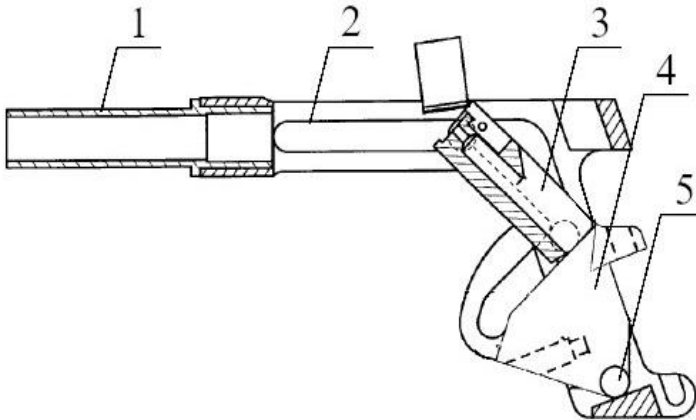


Fig. 13. DBO patented for the Kriss Vector: 1 – barrel; 2 – guide cam; 3 – bolt head; 4 – bolt carrier; 5 – cam pin (fig. based on [35])

4. CONCLUSIONS

While not as popular as GO action, the delayed blowback operation, is an action principle widely applied in automatic firearms. In general terms, it is most popular in pistols, submachine guns, and assault rifles, and less frequently used in battle rifles. DBO machine guns, sniper rifles, shotguns, and grenade launchers exist. In recent years, DBO use has seen increasing popularity in PDWs.

The gas delay is now almost entirely limited to pistols, although most precursors of the operation were rifles. The roller delay can be found in almost every automatic small arm type, largely due to the design preferences of Heckler & Koch. The lever delay is found first in assault rifles and battle rifles.

The most popular DBO designs include those already listed in this conclusion, which have been used in small arms for decades. The solutions invented in the last decade are also interesting, primarily the radial DBO solution used in the CMMG Mk 45 Guard SMG and the patented Kriss DBO in the Vector SMG. Other DBO designs also have advantages but they see rare use in modern firearms.

To conclude, delayed blowback is a method of operation which provides many benefits, which first include:

- ✓ Reduction of the recoil acting on and felt by the operator;
- ✓ Compared to SBO small arms, the firearm's weight can be significantly lower, which also applies to the bolt assembly weight;
- ✓ Cartridges with a higher muzzle energy than available in pistol rounds can be used;
- ✓ While limited, DBO firearms can be adapted for different calibres or cartridge types;
- ✓ The simplified design and improved accuracy resulting from the fixed barrel and the light-weight bolt assembly;
- ✓ Control over the propellant gas effect on the automatic action in gas DBO by application of gas regulators or vents;
- ✓ The small arms can be configured in DIY shop conditions by for instance replacement of the control member with another one (applies to roller DBO small arms);
- ✓ Easy interchangeability of fast wearing components (like rollers or levers).

Despite the numerous benefits of DBO application, in some cases it is less advantageous than other firearm operation types. Note that DBO small arms are:

- ✗ usually more complex in the design of the bolt assembly in comparison to SBO breechblock and require a higher precision in the production processing of components;
- ✗ more sensitive to variations in the same ammunition types, where variations in the progression and value of propellant gas pressure or modifications of the case material may cause the weapon to jam or the action to work improperly;

- ✘ prone to overheating around the gas chamber and requires thorough and frequent cleaning;
- ✘ small arms adjustment of the action is difficult when the barrel length is changed, for example (a shorter barrel will reduce the duration of the gas effect on the bolt); the adjustment is often impossible without swapping components (the breechblock parts) (this does not apply to all DBO firearms).

With the sheer diversity of potential modifications to DBO, plans are in place to develop it further. Theoretical and experimental research of gas piston, roller, and lever DBO designs will help to improve and optimise the mating of the components in the DBO small arms. The results could be applied in the design engineering of modern armament in response to current needs of the military.

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Broń działająca na zasadzie odrzutu zamka półswobodnego w systematyce broni strzeleckiej

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Streszczenie. W artykule przedstawiono ogólną zasadę działania broni strzeleckiej wykorzystującej odrzut zamka półswobodnego, dokonano jej podziału w zależności od rodzaju zastosowanego opóźnienia, a także omówiono występujące konstrukcje. Na podstawie przeprowadzonej analizy dokonano oceny rozwiązań. Wyniki posłużą do dalszych rozważań i badań broni z zamkiem półswobodnym.

Słowa kluczowe: inżynieria mechaniczna, broń strzelecka, konstrukcja broni, systematyka, odrzut zamka półswobodnego