

The invention relates to a fin-stabilised sub-calibre projectile with discarding sabot according to the concept of claim 1.

From the DE-A-2 924 217 is known a fin-stabilised sub-calibre projectile of this type, the stabilising fin assembly is mounted on the projectile to be rotatable around the projectile's longitudinal axis. On the sabot is provided a slipping guide band in order to achieve a spin for transfer to the projectile during launch and, at the same time, for a reduction of the spin acting on the fin assembly, in which respect the rotatable fin assembly is to get rid of the projectile dispersion pattern and range which are adversely affected by residual spin.

Furthermore, from the GB-A-2 027 855 is known a process for the manufacture of a sub-calibre projectile, in which the discarding sabot is cast in a simple manner directly onto the projectile body, in which respect the full spin is transferred to the projectile. The projectile can be constructed in particular as a sweepback-wing projectile.

In contrast to conventional spin-stabilised projectiles which derive their in-flight stability from gyroscopic forces resulting from a high rate of spin, finned projectiles are stabilised during flight by aerodynamic forces acting on the projectile. Although projectile spin does not contribute to stabilisation of finned projectiles, a lower rate of roll around the longitudinal axis is desirable for minimising adverse effects of mass and configurational asymmetries resulting from material imperfections and from manufacturing tolerances.

Fin-stabilised projectiles are preferably launched from smooth-bore guns. Due to the absence of rifling grooves, no spin is produced. Weapons of this type are installed, for example, on advanced battle tanks, commonly having a calibre of 60 millimetres or more.

Automatic guns with a calibre range between 12.7 and 40 millimetres usually have rifled barrels for launching different types of spin-stabilised projectiles, in particular armour-piercing projectiles. In order to improve the armour-piercing capability of these weapons, it is desired to develop technology permitting successful employment of fin-stabilised, long armour-piercing projectiles with their inherent terminal effectiveness launched from rifled barrels. In this case, successful employment means compatibility of the ammunition with a weapon and feeder system, which itself requires the necessary structural integrity to function reliably under all conditions, to produce a projectile precision which is equal to or better than that of spin-stabilised projectiles which are launched from the same weapon.

Fin-stabilised projectiles are usually composed of a sub-calibre projectile body and a fin assembly of four or more individual fins which are attached to the rear end of the projectile. The projectile assembly is symmetrical relative to its longitudinal axis, and the projectile is launched from the weapon by means of a discarding sabot. The discarding sabot has to fulfill two important tasks. It has to guide the sub-calibre projectile along the centre line of the gun barrel during acceleration, and it has to form a seal to contain the propellant gases during its travel in the barrel. The latter task is fulfilled by the rotating band which engages the rifling grooves of the gun barrel whilst imparting the full spin to the projectile

commensurate with the increase in rifling twist and muzzle velocity of the projectile.

Fin-stabilised projectiles of the present state of the art have a sliding seat between the rotating band and the sabot. The sliding seat is arranged so that it reduces the rate of spin of the sabot by approximately between 70 and 90% of the spin of the rotating band which picks up the full spin. The magnitude of spin imparted by the sliding seat in the rotating band is determined by sliding friction. Thus, on exit of the projectile from the gun muzzle, the fin-stabilised projectile has a rate of spin of approximately 10 to 30% of the rate of spin of a spin-stabilised projectile launched from the same gun barrel.

There are two problem areas to be observed with this type of launching fin-stabilised projectiles from rifled barrels. Firstly, it is difficult to control the spin reduction by the sliding seat with the required repeatability so as to ensure acceptable projectile accuracy over the entire range of launching conditions in military applications. Changes in projectile temperature between -40 and $+60^{\circ}$, changes in humidity, manufacturing tolerances, contamination by dust, salt or other substances which enter between the rotating band and its seat, affect the friction coefficient in the seat of the rotating band and thus the magnitude of spin transfer.

Secondly, centrifugal forces which act on sections of the sabot are effective in initiating an immediate and symmetrical separation of the sabot from the projectile body on exit of the projectile from the gun muzzle. With reduced projectile spin, the centrifugal forces are also reduced, which act on the sections of the sabot, namely by the square of the rate of spin. As a result, the separation of the sabot is not as rapid and

less-precise than with non-sliding rotating band, and increasingly more dependent on aerodynamic forces.

The effect of aerodynamic forces on the projectile is delayed by the escape of propellant gases on exit of the projectile from the gun muzzle. These propellant gasses temporarily envelop the projectile in a reverse-flow field. The aerodynamic forces become fully effective for separating the sabot after entry into the atmosphere, which occurs approximately at a distance of about 30 calibres away from the muzzle. The magnitude of the aerodynamic forces which are effective for separating the sabot is only a fraction of the centrifugal forces available when launching at full rate of spin. Therefore, a substantially more fragile sabot construction is required in order to ensure its break-up and separation. Furthermore, due to the limitation of ammunition to a calibre up to 40 millimetre, the dimensions of the sliding rotating band together with its seat are very small, thus presenting sensitive and fragile parts.

In contrast thereto, the use of non-sliding rotating bands permits the assembly of stronger sabots. This is of advantage in conjunction with rapid-fire guns and corresponding structural load during feeding and ramming into the gun barrel.

Experience has shown that fin-stabilised projectiles having a discarding sabot with sliding rotating band produce considerable differences in the rate of spin on exit from the muzzle due to deviations in the friction coefficient on the sliding seat of the rotating band. Accordingly, subsequent acceleration or retardation of the projectile spin can cause conditions in which the rate of spin equals that of the nutation frequency of the projectile, and instability in resonance can occur. The smaller the projectile spin on exit from the gun

muzzle, and thus the centrifugal forces acting on the sabot, the smaller is the speed and the symmetry when discarding parts of the sabot, thereby increasing projectile dispersion.

To sum up, the following disadvantages are encountered with respect to discarding sabots on fin-stabilised projectiles for automatic guns with sliding rotating bands for spin reduction:

- 1: Considerable fluctuations in projectile spin during launch due to fluctuations in friction coefficients in the seat of the rotating band.
- 2: Fluctuations in projectile spin during launch resulting in reduced repeatability of sabot separation and thus of the trajectory, thereby increasing projectile dispersion and reducing the probability of a first-time hit.
- 3: Reduction of projectile spin during launch reduces the centrifugal forces which are required for sabot separation, necessitating a weaker construction of the sabot. The loss in rigidity and reliability is further aggravated by the sensitivity of the sliding rotating band and the seat.

Proponents of the use of sliding rotating bands erroneously assume that there is a high aerodynamic flow resistance during the aerodynamic spin reduction of the projectile having a full rate of spin during launch. However, launching tests have revealed that the effective flow resistance is very low, which is not surprising when taking into consideration that the spin energy of fin-stabilised sub-calibre projectiles is less than one percent of its translatory kinetic energy. In this context, it is also of interest that the maximum projectile yaw during launch was less than five degrees due to the precise and symmetrical sabot

separation of fin-stabilised projectiles at full rate of spin. This low initial yaw is very desirable for minimising the aerodynamic resistance and the projectile retardation.

It is an object of the present invention to improve the hit-probability of fin-stabilised sub-calibre projectiles which are launched from rifled gun barrels, by definition of projectile properties which permit launching at full rate of spin and without the use of a rotating band for spin reduction. Furthermore, dispensing with the fragile sliding rotating band permits improvement of the structural integrity, rigidity and reliability of the ammunition.

The invention relates in particular to fin-stabilised projectiles for automatic weapons of a calibre between 12.7 and 40 millimetres. A discarding sabot with rigidly mounted rotating band produces a spin during acceleration of the projectile in the barrel corresponding with the twist of the rifling grooves and the muzzle speed of the gun barrel. The resulting spin on launch is thus exclusively dependent on the muzzle speed, and thus precisely repeatable. The spinning action is transferred without loss to the sub-calibre projectile. Following the exit from the gun barrel and after separation of the sabot, the sub-calibre projectile enters into the atmosphere and is exposed to aerodynamic forces. The aerodynamic forces both stabilise the projectile in flight and act on the fins, causing rapid reduction of the rate of spin of the projectile. After a relatively short flight period, the rate of spin arrives at a constant value. This constant rate of spin is determined by the cant angle of the fins, and it is proportional to the projectile flight speed. In order to maintain stable flight conditions and to avoid deviations from the trajectory,

it is necessary that the constant rate of spin of the projectile is higher than the nutation or natural frequency. This selection of a constant rate of spin is to prevent the occurrence of resonance instabilities which cause a large angle of attack and even catastrophic fluctuations. The critical rate of spin (nutation frequency) of the projectile is determined by the inertia moment and aerodynamic properties and represents a fixed value for a specified projectile. The magnitude of the critical spin can be influenced within certain limits by the design of the projectile.

The fin-stabilised projectile is provided with a discarding sabot having substantially three main components, i.e. a sabot base, a sabot body and a protective cap. The sabot base is preferably made of a light alloy, in particular aluminium, composed of three or more identical elements and holding the penetrator in the central area in a coaxial position relative to the gun barrel. The sabot base transfers longitudinally directed accelerating forces and the spin, which is transmitted via the rifling grooves from the sabot to the penetrator. A sabot body of plastics material is arranged in front of the sabot base and provided with an integrated rotating band which engages the rifling grooves, provided both for sealing and for transfer of the spin motion which is transferred from the rifling grooves to the penetrator. The sabot body further envelops three or more longitudinal grooves, which extend radially from its outer cylindrical surface and leave a web of finite thickness on the inside of the longitudinal grooves. The sabot will break up along these longitudinal grooves under the effect of a centrifugal force on exit from the gun muzzle.

According to a substantial feature of the sabot design, there is a mechanical link between sabot body and sabot

base which interconnects the front portion of the sabot base and the rear portion of the sabot body. This link prevents separation of the parts under the effect of propellant-gas pressure acting on the rear side of the rotating band during the launch. Furthermore, the link transfers the spin from the sabot body to the sabot base.

According to a further important feature of the present invention, the separating surfaces are sealed between the parts of the sabot base, and the connection between the rear of the sabot base and the penetrator is provided with an annular seal. The seal of the rear parts, the annular seal and the sabot body are one single integrated unit, preferably of a fibre-reinforced plastics material. Due to the complicated configuration of sabot body and seals, this unit is preferably produced by way of an injection-moulding process on the previously assembled unit of sabot base and penetrator.

A protective cap is fitted on the forward end of the sabot body so as to protect the forward end of the penetrator and to match the projectile to the automatic feed system.

Subsequent to sabot separation, the induced reduction of the projectile spin to a constant projectile spin is very rapid, very precise and repeatable. This is combined with the fact that the initial rate of spin on the muzzle is as precisely controllable as the muzzle speed. Generally, the deviation from standard is not more than one percent and produces a precisely repeatable performance of the projectile spin whilst in flight.

The full spin obtained with a fixed, non-sliding rotating band causes high centrifugal forces which act

on the sabot parts and which are required for immediate and symmetric radial separation on exit of the projectile from the muzzle. This method of sabot separation, combined with controlled projectile-spin reduction along the trajectory, as is possible with projectiles having a fixed rotational band, produces a projectile accuracy not previously achievable with conventional projectiles.

It is an object of the invention to create a fin-stabilised projectile with discarding sabot, which is launched from a rifled barrel with full spin corresponding with the pitch of the rifling grooves of the gun barrel.

The invention further creates a fin-stabilised projectile with discarding sabot, which is launched with full twist from a rifled barrel and subsequently retarded in a rapid, precise and precisely repeatable manner to a constant rate of spin by means of aerodynamic damping, resulting in precisely repeatable spin reduction during the flight of the projectile.

It is a further object of the invention to create a fin-stabilised projectile with discarding sabot, which is launched from a rifled barrel, achieving full spin during the launch and having a constant rate of spin which is greater than the nutation frequency of the projectile.

The invention further aims at creating a fin-stabilised projectile with discarding sabot, which is launched with full spin from a rifled barrel, having a spin half life of not more than 0.1 seconds, in which respect this half life period is required for lowering the rate of spin to a value half way between initial value on launch and the constant rate of spin.

It is a further aim of the invention to create a fin-stabilised projectile having a robust sabot which is immediately and radial-symmetrically separated after launch under the effect of centrifugal forces.

It is a further aim of the invention to create a discarding sabot for a fin-stabilised projectile, in which respect the sabot comprises three elements, namely a sabot base, a sabot body of plastics material with integrated rotating band and seals and a ballistic protective cap.

It is a further object of the invention to create a discarding sabot for a fin-stabilised projectile, in which sabot base and sabot body are mechanically linked and the sabot body comprises an integral rotating band for sealing the propellant gases and for transferring the full spin, which is produced via the rifling grooves of the barrel, to the projectile.

The invention further aims at creating a disbanding sabot for a fin-stabilised projectile, in which the sabot body comprises an integrated rotating band for sealing the propellant gases in rifling grooves, and a seal which extends over the intermediate surfaces of the sabot base parts, and with a seal at the contact surface between sabot base and penetrator.

It is a further object of the invention to create a disbanding sabot for a fin-stabilised projectile having an integrated construction of sabot body, rotating band and seal of the base part elements and seal between base and penetrator.

The invention further aims at creating a sabot body for a fin-stabilised projectile, which is directly cast in an injection-moulding process onto the sabot base which is combined with the penetrator.

These and other features of the invention are easier to understand by way of the following description of the invention.

The invention will now be described, based on an exemplary embodiment which is illustrated in the enclosed drawing. Shown are, in

- Fig. 1: a longitudinal section through a fin-stabilised sub-calibre projectile with disbanding sabot;
- Fig. 2: a longitudinal view of a fin-stabilised sub-calibre projectile;
- Fig. 3: a diagram of the rate of spin of the fin-stabilised projectile as a function of range travelled;
- Fig. 4: a longitudinal section through the fin-stabilised sub-calibre projectile with disbanding sabot;
- Fig. 5: a cross-section through the sub-calibre projectile along the line 4-4 in Fig. 4;
- Fig. 6: a cross-section of the sabot body and the sub-calibre projectile along the line 2-2 in Fig. 4;
- Fig. 7: a cross-section through the sabot base and the sub-calibre projectile along the line 3-3 in Fig. 4;
- Fig. 8: a section through the finned rear end of the penetrator; and
- Fig. 9: a rear view of this penetrator.

Fig. 1 illustrates a longitudinal section through a sub-calibre projectile which is located in a discarding sabot. The sub-calibre projectile comprises a penetrator 10 and a fin arrangement 12 at its rear end.

For many applications, a pyrotechnic tracer 14 is provided, which is usually located in the central body of the fin arrangement. In order to obtain high penetration efficiency, a heavy metal, in particular a tungsten alloy or enriched uranium alloy, is used for the penetrator 10. Steel or aluminium is used for the production of the fin arrangement. In the case of high-velocity projectiles, the aluminium fins must be provided with protective layer in order to prevent burning due to aerodynamic heating.

The fin arrangement usually comprises between 4 and 6 fins, which are arranged symmetrically around the central body. Fig. 2 illustrates a fin arrangement comprising four fins. Because of gun constraints, the fin span 16 has to be equal or smaller than the bore diameter of the barrel. In order to reduce aerodynamic flow resistance, the forward edge of the fins is swept back like an arrow, in which respect the fins are relatively thin. The planform of the fins has to be sufficiently large so as to ensure aerodynamic stability in the longitudinal direction of the sub-calibre projectile within a stability margin of not less than 1.5 sub-calibre-projectile diameters, in which respect the stability margin is defined as the distance of the aerodynamic pressure centre 24 relative to the centre of mass 26 of the projectile body.

According to the invention, the fin arrangement is to produce an aerodynamic rolling or transverse moment relative to the longitudinal axis 20 of the projectile, in order to ensure a constant rate of spin during flight, corresponding with a propeller drive. The rolling moment is aerodynamically produced, either by the attack angle of the fins, similar to the stabiliser fins on an aircraft, or by a canted guide edge 22 of the fins as shown in Fig. 2, or by canted

trailing edges of the fins. All fins are preferably identically shaped.

It is a main object of the invention that the sub-calibre projectile is imparted full spin in accordance with rifling twist and the muzzle velocity of the gun barrel. This requires that the discarding sabot comprises a rigidly mounted rotating band which transfers the spin produced by the rifling grooves to the sub-calibre projectile without slippage. On exit of the projectile from the muzzle and separation of the sabot, the sub-calibre projectile enters the atmosphere and is immediately subjected to spin-reducing aerodynamic damping. The rapid spin deceleration continues until a constant spin commensurate with the fin configuration and the projectile speed is achieved. The spin half life, i.e. the time required for reducing the spin rate of the projectile to half the value between the initial value at launch and steady spin rate, should not exceed 0.1 seconds. During this phase, the projectile is given increasing dynamic stability, and the spin half life is in excess of 0.1 seconds and as such too short to permit a potential increase of precession movement due to Magnus forces.

It is a further object of the invention to determine a constant spin rate of the sub-calibre projectile in order to prevent both the occurrence of resonance instabilities and respective resonance jumps during the flight of the projectile. Rotating fin-stabilised projectiles are exposed to resonance instabilities. These are conditions in which the projectile spin equals the nutation frequency or natural frequency of the projectile. They are characterised by an increase of a non-rolling trim angle of attack resulting from configurational asymmetries, for example as caused by manufacturing tolerances or material imperfections. The

nutaton frequency ω_i of a fin-stabilised projectile is determined by tricyclic theory of motion in accordance with the following equation:

$$\omega_i = \frac{p}{2} \frac{I_A}{I_T} \left(1 + \frac{1}{\tau} \right) ; \tau = \frac{1}{1 - \frac{1}{s}}$$

p = rate of spin

I_A = axial moment of inertia

I_T = transverse moment of inertia

s = gyroscopic stability factor.

Resonance instability causes large angles of attack and consequently unacceptable projectile dispersion. Furthermore, the resonance can be accompanied by spin movements and yaw. In order to prevent the occurrence of resonance instability, the constant rate of spin has to differ from the nutation frequency of the projectile. It is an object of the present invention to reduce the rate of spin of the projectile rapidly from its initial value at launch to the constant rate of spin which exceeds that of the nutation frequency of the projectile by at least a factor of two under all conditions within the operational range of the ammunition. This method, which is also described as rate-of-spin tuning, is described further in another example of Fig. 3. The illustration represents the rate of spin of the projectile as a function of trajectory range for a fin-stabilised projectile which is launched from an automatic 25mm gun with a rifling twist of 7.5%. At a muzzle velocity of 1300 metres/sec, the corresponding rate of spin is 13,690 rad/sec. Subsequent to sabot separation, the spin rate of the projectile reduces rapidly due to aerodynamic rate-of-spin damping. The spin half life (7,505 rad/sec) is

attained after 0.058 seconds and in accordance with a projectile speed of 1,300 m/sec at a distance of 75 metres from the gun. At a distance of approximately 600 metres from the gun, the projectile has a constant spin speed of approximately 1,320 rad/sec. This rate of spin will decrease further proportionally to the projectile speed. At a horizontal distance of approximately 2,000 metres from the gun, the projectile speed is still approximately 1,200 m/sec, and the constant spin is still approximately 1,106 rad/sec. The natural frequency of the projectile is approximately 440 rad/sec. Thus, with maximal range of the projectile, the constant rate of spin is still greater by a factor of 2.5 than the nutation frequency, so that resonance instability is avoided. The presented data are based on test launches and indicate the effect of spin tuning, which is an object of the present invention.

It is a further object of the invention to provide a discarding sabot for a fin-stabilised sub-calibre projectile. According to a preferred exemplary embodiment, the discarding sabot comprises three main components, as illustrated in a longitudinal section in Fig. 4. The extreme rear component is a sabot base part 28, comprising three or more identical elements 29, which house the penetrator 10 of the sub-calibre projectile in a coaxial position. These three elements 29 make contact with each other along the radially oriented plane surface 30. The arrangement of the sabot base part 28 is also described as based on Fig. 5, giving a rear view of the discarding sabot. The contact surface of the sabot base part and the middle part of the penetrator 10 serves several functions. Firstly, this surface places the penetrator in a coaxial position relative to the barrel axis. Secondly, the contact surface has to be sufficiently strong for the

transfer of longitudinally acting accelerating forces from the sabot to the projectile at launch. Thirdly, the contact surface is to transfer, without slippage, the spin which is induced via the rifling grooves of the gun barrel from the sabot to the penetrator. The aforescribed functions are performed at their best by means of a threaded surface 32 or by a number of annular grooves.

A further component of the discarding sabot is the sabot body 34, which is made of plastics material and which is located in front of the sabot base, as is shown in Fig. 4. The sabot body comprises an integrated rotating band 36 which, on launch, engages the rifling grooves of the gun barrel and also serves as a seal for the propellant gases and the transfer of the spin motion which is transferred from the rifling grooves of the gun barrel to the sub-calibre projectile. The sabot body 34 comprises three or more longitudinally extending grooves 38 which also extend in the radial direction from the outer cylinder surface up to the penetrator 10 and to the sabot base 28, so that a web 40 remains, which has a finite thickness at the interior limit of the groove 38. These longitudinal grooves are illustrated in Figs. 4 and 6. On exit of the projectile from the gun muzzle, the sabot immediately breaks up along these webs 40 due to centrifugal forces produced by the high spin. The presence of these webs ensures sealing against entry of water and other harmful effects during storage and transport of the ammunition.

There are two critical constructional features which are substantial with respect to successful operation of the sabot body 34. The first features relates to the constructional arrangement of the contact surface 42 between the front part of the sabot base 28 and the

rear part of the sabot body 34 as in Fig. 4. This mechanical connection is necessary for anchoring the sabot body 34 on the sabot rear 28, so as to prevent separation of these two components due to the effect of propellant-gas forces which act on the rear end of the rotating band 36 during launch, and for transferring the spin from the sabot body to the sabot rear. The arrangement of this connection is such that the effectiveness of the gas seal between sabot body 34 and sabot rear 28 increases with the gas pressure on the rotating band during launch in the gun barrel.

The form of connection is dictated by the external contour of the frontal two thirds of the base surface in front of the detent groove 43 for the cartridge, in which respect this contour is located substantially under the rotating band of the sabot body. When launching the projectile, the rotating band and the sabot body are pressed together and form an effective gas seal along the intermediate surface, thereby preventing passage of propellant gases through this intermediate surface. Furthermore, the sabot body transfers the spin, which is produced by the rifling grooves, via the sabot base and without slipping to the penetrator 10 on the mechanical connecting surface.

The second critical feature is the seal 44, which extends rearwardly through the channels 41 located in the contact surfaces of the sabot-base segments. On the rear end of the sabot base 28, the seal, which extends through the channels, projects into an annular seal 46, which is located at the rear 37 of the sabot base 28 and surrounds the penetrator 10. The rear 37 also surrounds an annular groove 39 for anchoring the annular seal 46. The seal 44 is also shown in Fig. 7, illustrating a cross-section through the sabot base 28. This seal is essential in preventing propellant gases

from entering the sabot arrangement during launch either through the contact surfaces 30 of the sabot-base segments or along the periphery of the penetrator 10. The seal 44 and the seal 46 and the sabot body are one single integral unit which, because of its complicated configuration, is produced in an injection-moulding process in a single operation on a previously assembled sabot base. This on-location manufacture in an injection-moulding process on the sabot base requires a special mould into which the projectile-sabot-base sub-assembly is installed and centred, so as to ensure coaxial alignment of all components.

The cross-section of the seal 44 and the corresponding channels in the contact surfaces 30 of the sabot segments 28 can be larger than shown in Fig. 4. However, it is essential that the sabot body 34, the seal 44 and the obturator 46 are one integral unit. Preferably, a carbon and fibre-glass reinforced plastics material is used, for example nylon or liquid crystal polymer (LCP), which is suitable for on-location injection-moulding for the sabot body as a seal and obturator.

A third substantial component of the discarding sabot is the protective cap 48 which is mounted on the forward end of the sabot body. The exterior shape must meet the surface requirements of the ammunition of guns. The cap is necessary to protect the sub-calibre-projectile portion which protrudes over the front end of the sabot body whilst the ammunition is stored, transported and fed to the gun. To reduce the weight of the cap, it is hollow and made of a thin wall and preferably of plastics material by way of injection moulding. The protective cap is preferably attached to the sabot body by means of a snap fitting 50.

As aforementioned, the stability of the projectile, i.e. the distance S between the centre of mass 26 of the penetrator 10 and the air-engaging point 24 on the penetrator 10, is dependent on the configuration of the stabilising fin 12. Equally, the spin half life on the one hand, and the magnitude of the constant spin are dependent on the configuration of the stabilising fins 12. As explained, this distance S between centre of mass 26 and air-engaging point 24 should be greater by a minimum of 1.2 times than the sub-calibre diameter of the penetrator 10. The spin half life is to be 0.10 seconds, and the constant spin is to be 50% greater than the nutation frequency or natural frequency of the penetrator 10, as is illustrated in Fig. 3. The properties of the penetrator 10 are achieved by respective configuration of the stabilising fins 12. Therefore, the construction of the four stabilising fins 12 will now be described in more detail, based on Figs. 8 and 9.

According to Fig. 8, the canted guide edge 22 is slanted, for example by 30° , comprising a second canting of 10° as in the section A-A. According to view B, this is a 5° canting. It is significant that the fins 12 are canted on one side only, namely on the rear or remote side, as seen in the spin direction of the projectile. Finally, the fin length a in Fig. 8 is of significance relative to the stability of the penetrator 10.

According to Fig. 9, the four fins 12 are evenly spaced around the periphery and relatively thin, i.e. for example 0.5 - 1.0 millimetres. According to Fig. 8, view B, the edge 22 is more or less sharp, i.e. the value b is between 0 - 70% of the fin thickness. The following value can be given relative to the position of the centre of mass 26 and the air-engaging point

24: According to Fig. 2, the distance S1 between the tip of the penetrator 10 and the centre of mass 26 is, for example, 86 - 93 millimetres, and the distance S2 between the tip of the penetrator 10 and the air-engaging point 24 is, for example, 100 - 120 millimetres. The stability of the penetrator 10 thus results from the difference S2-S1 and the diameter of the penetrator 10.



Patent Claims

- 1: Fin-stabilised sub-calibre projectile with discarding sabot for launching from a refiled gun barrel, having a penetrator (10), which consists of a long rod with a set of stabilising fins (12) arranged at its rear, **characterised in that** a sabot is provided for transferring the full spin commensurate with the rifling twist and the muzzle speed to the projectile, that the stabilising fins (12) are attached in a fixed location on the penetrator (10), and that the aerodynamic shape of the stabilising fins (12) is such that the penetrator (10), whilst in flight, has a minimum of longitudinal stability (distance of the aerodynamic pressure centre (24) behind the centre of mass (26) of the sub-calibre projectile) of 1.2 penetrator diameter, aerodynamic roll damping causing a spin half life of not more than 0.10 seconds, and subsequently a constant rate of spin which is at least 50% greater than a given nutation frequency of the projectile.
- 2: Fin-stabilised sub-calibre projectile according to claim 1, **characterised by** aerodynamic roll damping producing a spin half life which is smaller than the time for changes in the projectile precession due to the Magnus effect.
- 3: Fin-stabilised sub-calibre projectile according to claim 1, **characterised in that** the penetrator (10) is provided with sufficient aerodynamic damping for its nutation and precession



movement, from which is derived an increasing dynamic stability when the roll movement of the projectile reduces.

- 4: Fin-stabilised sub-calibre projectile according to claim 1, **characterised** by a constant rate of spin so as to avoid the occurrence of resonance jumps and roll movements or catastrophic yaws of the projectile during its entire flight.
- 5: Fin-stabilised sub-calibre projectile according to one of claims 1 to 4, **characterised** in that the stabilising fins (12) are at their guide edge (22) rearwardly swept back and also canted, as seen in the direction of spin, so that the desired longitudinal stability, spin half life and constant rate of spin are established.
- 6: Fin-stabilised sub-calibre projectile according to claim 5, **characterised** in that furthermore the length of the stabilising fins (12) in the axial direction is chosen so that the desired longitudinal stability, spin half life and constant rate of spin are established.
- 7: Fin-stabilised sub-calibre projectile according to one of claims 1 to 6, **characterised** by a sabot comprising a segmented, metallic rear (28) with a number of intermediate surfaces (30) and means for non-rotational accommodation of the penetrator (10) in the region of the centre of mass (26) and along the longitudinal axis (20), a sabot body (34) of plastics material, which is attached to the body (28), extends therefrom forward along the projectile axis (20) and comprises an integrated rotating band (36), so as to give the penetrator (10) non-slip spin, as well as means (44, 46) for sealing the base



intermediate surfaces (30) and for sealing the connection between penetrator (10) and base (28).

- 8: Fin-stabilised sub-calibre projectile according to claim 7, characterised by an injection-moulded sabot body (34), comprising an integrated seal (44, 46), which extends rearwardly through longitudinally extending slots (30) of the metallic sabot base (28) and forms an annular obturator (46) which envelops the penetrator (10) at the rear of the base (28), in which respect the obturator (44, 46) prevents propellant gases from entering the sabot (28, 34) between longitudinally extending segments (29) of the base portion (28) and the connection (32) of penetrator (10) and sabot (28, 34).
- 9: Fin-stabilised sub-calibre projectile according to claim 8, characterised in that the base (28) has a connecting surface (42) which extends forward so as to engage the sabot body (34) which also accommodates the penetrator (10) in a coaxial position.