

Description

The invention relates to small-arms ammunition, comprising an axially symmetrical projectile, a cartridge case with a powder charge and a primer disposed centrally with respect to the longitudinal axis thereof, the cartridge case being secured in a portion between the flattened tip of the projectile and its rear end. The invention also relates to a method of manufacturing the small-arms ammunition and to an application of the method.

The term "small-arms ammunition" is used to mean ammunition having a calibre below 12.7 mm, more particularly a calibre in the range from 4 to 6.35 mm.

An axially symmetrical jacketed projectile is known from the US Department of Commerce, National Technical Information Service Publication No. AD-A025 131 (Michael Pino, "The Effect of Varying certain Parameters on the Performance of the S.C.A.M.P. produced 5.56 mm Projectile", DARCOM Intern Training Center, May 1976). The known projectile has an ogival profiled part, a cylindrical middle part and a frusto-conical rear end part. The profile part as described is parabolic conical or spherical. It is expressly stated that a change in the profile part necessitates a change in the construction of the firearm. DE-A 25 25 230 describes and illustrates a method of manufacturing jacketed projectiles and the projectile produced by the method. In the case of this

projectile, the curvature of its tip alters but is not precisely defined, so that the curvature can be judged only in accordance with the drawing. During manufacture, the projectile is shaped and cut from a tubular blank in known manner. US-A 2301 565 and US-A 2 920 374 describe various ways of shaping the jacket of the projectile. Various tools are used in a number of steps. The shapes of the projectile jacket are not mathematically defined and can only be read inaccurately from the drawings.

It is known that the effects are produced by changes in the shape of the tip and/or the rear end with regard to the ballistic properties of the projectile.

The aim of the invention is to design a projectile of the intially-mentioned kind which has improved accuracy and hits with greater ballistic energy.

Another aim is to devise a method of producing an aforementioned jacketed projectile which, in spite of greater piercing power, is economic for large-scale manufacture. In addition, the projectile must not disintegrate in the target and must meet the requirements of the CICR (Comité International de la Croix-Rouge).

According to the invention the aforementioned problem is characterised in that the profile of the projectile is defined by a summation function

$$r(x) = r_1(x_1) + r_2(x_2)$$

in which the range of x_1 is given by

$$x_1 = \frac{h}{2}(1 - \cos a) - \frac{s}{2}(1 + \cos a).$$

in which h is an imaginary length of x_1 for $a = \pi$ up to an imaginary tip of the projectile and arc cos

$$\frac{h-s}{h+s} \leq a \leq \pi$$

and the associated values of r_1 are given by

$$r_1 = r_0 \sqrt{\frac{1}{\pi} (a - \frac{1}{2} \sin 2a)}$$

in which arc cos

$$\frac{h-s}{h+s} \leq a \leq \pi$$

and in which the range of x_2 is defined by

$$x_2 > h$$

in which $r_2 = \text{const.} = r_0$, the imaginary tip of the projectile being remote by a distance $(-s)$ from the origin of a right-angled system of coordinates, the positive X-axis of which is an axis of symmetry and the Y-axis of which represents a direction of the radius r of the projectile and the actual tip of the projectile is situated at the origin of the system of coordinates.

The invention is based on the surprising discovery that, contrary to the expectation of the experts, the accuracy of small-arms ammunition is very advantageously influenced by an aerodynamic shape, in spite of the small

size, the short range and the relatively short time in flight, typical of such projectiles.

The continuous function $r(x)$ disclosed in the claim substantially describes the profile of the projectile. Of course, the required continuity cannot be completely achieved in practice at the ends of the projectile or at the place where the cartridge case is secured, but this does not adversely affect the teaching and the result.

The improvement is based on a mathematical formula by Haack for the shape of a projectile with minimum air resistance, and applicable to large-calibre projectiles with supersonic nozzle velocities (Oerlikon Taschenbuch, Werkzeugmaschinenfabrik Oerlikon-Bührle AG, Zürich, Switzerland, May 1981, Chapter 5.2.3. pages 168 to 171). This equation has been used to derive a parameter equation for designing a shape for the profiled part of small-arms ammunition which is improved as regards air resistance.

Advantageously according to claim 2 the portion for securing the cartridge sleeve is displaced into the region of x_2 by a distance in the range of 0.1 to 0.5 r_0 from the place corresponding to an upper limiting value of x_1 . As a result, a small piece of the cylindrical part projects from the cartridge case when the latter is connected to the jacketed projectile, thus improving the guidance properties.

Another advantageous feature according to claim 3 is characterised in that a rear end of the projectile comprises two substantially frusto-conical portions, the imaginary apices of which lie on the axis of

symmetry of the projectile, and the internal portion with respect to the end has an angle of taper in the range from 5 to 10° and a length in the range from 0.5 to 2 r_0 and the external portion with respect to the end has an angle of taper in the range of 60° and ends at a distance from the axis of symmetry of the projectile. A rear end having this shape further improves the stability and the flight properties of the projectile.

Advantageously according to claim 4 the projectile is a jacketed projectile having a jacket made of clad alloyed steel in which a heavy-metal core is inserted. Projectiles of this kind can be efficiently manufactured by deformation under tension and pressure. They can be shaped with the required accuracy, even in large-scale production.

Advantageously according to claim 5 the jacket at both ends has a grooved portion for securing it to the cartridge case.

The axially symmetrical jacketed projectiles for small-arms ammunition are manufactured as follows: a cylindrical cup flattened at the base is deep-drawn, after which, according to claim 6 of the invention, in a first step the pre-formed cup is elongated during subsequent drawing without altering the thickness of the base and the angle of the internal taper is reduced, in a second step the cylindrical part of the projectile is drawn and a flash collar is formed at the end, the

internal taper angle being further reduced, in a third step the tip of the projectile is pre-formed in a polished, smooth female die, in a fourth step the tip of the projectile is given its final shape in a second polished, smooth female die, in a fifth step the projectile is cut to its provisional length at the flash collar, in a sixth step a pre-formed heavy-metal core is pressed in to the projectile, in a seventh step the rear part of the projectile is given a conical shape, in an eighth step the rear edge is crimped over the heavy-metal core, in a ninth step the rear end of the projectile is given its final shape and in a tenth step the projectile is pushed through a female calibrating die. This method improves the deformation work per step of the process and, in spite of the high speed of the press, can be used to manufacture projectiles of high and reproducible quality.

Advantageously according to claim 7 the first to the tenth steps are interlinked and carried out on a single progressive press.

Advantageously according to claim 8 the aforementioned method is applied to the manufacture of a small-arms hard-lead core projectile. This application is particularly advantageous and well-tried.

Embodiments of the invention are shown in the Figures and will be explained and described in detail hereinafter with respect to the drawings in which:

Fig. 1 is a longitudinal section through a cartridge of the small-arms ammunition according to the invention;

Fig. 2 is a longitudinal section on a larger scale through a first embodiment of a jacketed projectile for the small-arms ammunition according to claim 1;

Fig. 3 is a very large-scale sectional view of the cup produced during the first drawing operation for small-arms ammunition and having a frusto-conical inner region thickened at the base;

Fig. 3a shows the cup in Fig. 3 in its size relative to the projectile in its final form;

Figs. 4 to 14 show the individual steps in the process of producing the final projectile, Fig. 9 showing the hard-lead core for pressing in, and

Fig. 15 is a larger-scale partial view of the male die used in the first pass of the subsequent drawing operation.

Fig. 1 is a view in longitudinal section of small-arms ammunition having a calibre of 5.56 mm, i.e. a conventional kind of small-arms ammunition. The ammunition comprises a conventional brass cartridge case 1 containing the powder charge 2 of conventional composition (e.g. a smokeless powder for small arms) and a jacketed projectile having a jacket 3 made of conventionally used material (e.g. of clad alloyed steel or high-copper non-ferrous metal or the like). The core 15 therein is

made of a conventionally used material such as lead or a lead alloy; alternatively core 15 can be made of steel or sintered material. The projectile has a front part 4 which is given an improved aerodynamic shape so as to reduce the air resistance to a minimum, as described in detail hereinafter. The projectile also comprises a substantially cylindrical middle part 5 and a substantially frusto-conical rear end 6. The middle part 5 has a grooved portion 7 for securing the jacket 3 to the cartridge case 1. Instead of the groove, the cylindrical middle part 5 can be milled for securing the cartridge case 1. The cylindrical middle part 5 extends from portion 7 by 0.254 mm outwards, corresponding to about $0.1 r_0$ where r_0 is the radius of the cylindrical middle part 5. The outwardly projecting extension can have a length in the range from 0.1 to $0.5 r_0$. The remaining portion of the cylindrical middle part 5 and the rear end 6 are enclosed in the cartridge case 1. A primer 11 is disposed in the closed end 10 of cartridge case 1 and is centred on the longitudinal axis of cartridge case 1.

The projectile is shown in detail in Fig. 2, on a larger scale and in longitudinal section. The front part 4 has a flattened end 12 of solid material. The cylindrical middle part 5, 5a with portion 7 and the rear end 6, comprising a frusto-conical portion 13 and another frusto-conical portion 14, contain a projectile core 15. In Fig. 2, the rounded front part 4 of the

projectile is denoted x_1 and the cylindrical middle part 5 and portion 5a are denoted x_2 . The distance of the end of the imaginary tip from the beginning of the cylindrical middle part 5, 5a, of the projectile is denoted h . In addition to the front part 4 and the middle part 5, the corresponding equalities for the radii r_1 and r_2 of the two parts are given. As Fig. 2 shows, the radius r_1 of the front part increases from the tip towards the cylindrical middle part 5a, 5, and its curvature decreases from the tip to the middle part until it continuously and steplessly merges into the cylindrical middle part 5a, 5.

The profile of the particle is defined by the parameter equation given hereinafter and derived from the known Haack equation and relating to a shape of high-calibre ammunition which has minimum air resistance, the air resistance being expressed by the air-resistance coefficient c_w . The actual tip of the jacketed projectile, as shown in Fig. 2, is at the origin of a rectangular coordinate system in which the height of the jacketed projectile is plotted along the positive X axis whereas the radius of the projectile extends in the Y direction. Except for the front end 12, the portion 7 and the rear end 6, the profile of the jacketed projectile is represented by a continuous function $y(x)$ having a continuous differential quotient $\frac{dy}{dx}$ which has a finite value.

This function is a summation function:

$$r(x) = r_1(x_1) + r_2(x_2).$$

This summation function has a region $r_1(x_1)$ associated with a continuously decreasing differential quotient, and a region $r_2(x_2)$ in which the differential quotient is constant and equal to zero. The summation function extends up to an imaginary tip of the jacketed projectile, which is displaced from the origin of the coordinate system by a distance $-s$.

Starting from the Haack equation for x , the following parameter equation is obtained for the first term of the aforementioned summation function:

$$x_1 = \frac{h}{2} (1 - \cos a) - \frac{s}{2} (1 + \cos a)$$

In this equation, x is the imaginary height of the jacketed projectile from the value for x_1 at $a = \pi$ to the imaginary tip; s is the displacement of the actual front end 12 relative to the imaginary tip, and a is a parameter which can assume any value within the range of arc cos :

$$\frac{h-s}{h+s} \leq a \leq \pi.$$

The other Haack equation can be used without difficulty to obtain the following parameter equation for r for the first term of the aforementioned summation function:

$$r_1 = r_0 \sqrt{\frac{1}{\pi} \left(a - \frac{1}{2} \sin 2a \right)}$$

In this expression, r is the radius of the cylindrical middle part 5 of the jacketed projectile, r_1 is the radius of the jacketed projectile in the region x_1 and arc cos

$$\frac{h-s}{h+s} \leq a \leq \pi$$

The second term in the aforementioned summation function relates to the region $x_2 \geq h$ and is defined by the equation

$$r_2(x_2) = \text{constant} = r_0$$

As can be seen immediately, the profile defined by the aforementioned summation function is characterised in that the transition between the ranges of x_1 and x_2 is absolutely continuous, since when $a = \pi$ the values of r_1 and r_2 are identical.

In the embodiment shown, s has a value of 0.65 mm or 0.232 units of the jacketed-projectile radius r_0 . However, s can take any value in the range from 0.1 to 0.5 r_0 . When the jacketed projectile is in flight, the front end 12 produces a given turbulence, thus avoiding instability due to what otherwise would be substantially laminar flow. The cylindrical middle part 5, which in the aforementioned formula corresponds to the region x_2 , has a grooved portion 7 for connecting to the cartridge case as per Fig. 1. Portion 7 can

be replaced by a milled portion. In the embodiment shown, the cylindrical middle part 5 extends beyond portion 7 by a distance 5a having an axial length of 0.25 mm or about $0.1 r_0$.

Portion 5a can have any value in the range from 0.1 to $0.5 r_0$. At the end remote from the front part 4, the middle part 5 is adjacent the rear part 6, which comprises two substantially frusto-conical portions 13 and 14. In this embodiment the inner portion 13 has an angle of taper of 8° , but can have any value in the range from 5° to 10° . Its length is 1.82 mm, corresponding to $0.65 r_0$. The outer portion 14 has an angle of taper of 60° , but can have other values in this range. This portion ends at a distance from the axis of symmetry. The aforementioned angles of taper each end in an imaginary cone tip, which lies outside the jacketed projectile and on an imaginary prolongation of the axis of symmetry. The aforementioned shape of the rear end 6 intensifies the effect of the previously-described profile on the properties of the projectile in flight, by advantageously influencing the stability and the air resistance.

The aforementioned jacketed projectile encloses a core 15 of lead or alloy, or made of another conventional material such as steel or sintered material. A particularly advantageous embodiment of the jacketed projectile comprises a variant of the rear end 6 in the inner frusto-conical portion 13, having a taper angle of only 7° and a length of 3.6 mm or $1.3 r_0$.

Jacketed projectiles according to the invention are manufactured by the following method:

To this end, Fig. 3 shows the cup 16 produced in a first drawing operation, of a kind similar to backward cup extrusion, from a round blank copper-plated or nickel-plated on both sides and punched from a steel sheet. The cup is given the reference 16 and has a cylindrical part 17 and a rounded part 18. An area 19 near the base is frusto-conical inwardly and rounded outwardly and has a greater wall thickness than its cylindrical part 17. The angle of taper of the inner cone is denoted α 1 and is about 20° .

Cup 16 is prefabricated in large quantities and is intended as a semi-finished product for intermediate storage. At the appropriate time, cup 16 is supplied to a progressive press having ten work stations and operated in a closed-top roll housing by a mono-slide driven by a crankshaft and two connecting rods at a speed of 120 cycles per minute.

The individual work stations are interlinked by the linear feed device. The cups 16 are supplied by a known vibrator having spiral guide tracks.

In the progressive press, the projectile is pressed into its final form in ten successive steps in the following sequence:

In a first step the semi-finished product in Fig. 3a is elongated as in Fig. 4 by a male die (Fig. 15) having a concave recess R at its end and a uniform base thickness,

the internal angle of taper alpha 2 being reduced to 10° .

In a second step the cylindrical part is drawn as in Fig. 5 and a flash collar is formed at the end from the superfluous material. In the process the internal angle of taper is further reduced; the wall thickness of the cylindrical part of the projectile already has the size for calibration.

In a third step the tip of the projectile is pre-shaped (Fig. 6) in a finely polished, smooth female die.

In a fourth work station the tip of the projectile is shaped (Fig. 7) likewise in a finely-polished smooth female die.

In a fifth step in the process, the projectile is cut to its provisional length (Fig. 8) at the flash collar.

In a sixth step a hard lead core (98% Pb + 2% Sb) and shaped as in Fig. 9 is prefabricated and pressed into the projectile. The resulting cross-section is shown in Fig. 10 where, as in the other drawings, the hard-lead core is represented by dots.

In a seventh work station the rear part of the projectile is pre-shaped in a female die, as shown in Fig. 11.

In the next step, as shown in Fig. 12, the rear edge is crimped above the heavy-metal core.

In a ninth step the rear part of the projectile is finely shaped as shown in Fig. 13.

In a tenth and last work station the projectile is calibrated in a female die.

Outside the progressive press, a crimp 20 for the cartridge case is produced by rolling in the cylindrical part of the projectile, as shown in section in Fig. 14.

The previously-described small-arms ammunition and the previously-described jacketed projectile are characterised in that, contrary to expectation, they have very considerable improvements in some important properties compared with known small-arms ammunition or known jacketed projectiles of this kind, in which the front part is ogival, i.e. parabolic, conical or spherical. The most important of these properties is the high accuracy of aiming the particle owing to its excellent surface shape. This is achieved without the use of special gun barrels for giving greater spin to the projectile. Firing tests have shown that many properties of the projectile are considerably improved, e.g. the dispersion in the horizontal and vertical axis of distribution is 30% to 60% better at ranges of 30 to 300m. The projectile also has a piercing power against light-armoured targets which is comparable with steel and hard-core projectiles which are considerably more expensive to make. The resistance to deformation and the improved piercing and penetration capacity are due to the solid tip of the projectile (see Figs. 11 to 14).

A projectile produced according to the invention has high strength in the target and disintegrates only under extreme conditions.

The following table gives experimental data for some important properties of known conventional ammunition

having a calibre of 5.56 mm and the corresponding values for ammunition according to the invention having the same calibre. The table also gives the percentage differences from values obtained with known ammunition.

Table

Comparison between absolute and relative tests data for a known projectile and for the invented jacketed projectile at various ranges.

Measured value	Range	Jacketed particles		
		Prior art	According to the invention Absolute	Relative (%)
Max. height	300 m	0.19	0.19 m	0
	500 m	0.73 m	0.66 m	-10
Time in flight	300 m	0.39 sec.	0.39 sec.	0
	500 m	0.76 sec.	0.74 sec.	-3
Final Ballistic Energy	300 m	706 J	879 J	+25
	500 m	357 J	525 J	+47
Cross-Wind Deflection	300 m	0.78 m	0.59 m	-24
	500 m	2.39 m	1.87 m	-22

As the table shows, the jacketed projectile according to the invention, which has an improved aerodynamic shape with regard to air resistance, has a less steep flight path and a somewhat shorter time in flight. It has considerably higher final ballistic energy, particularly at long range. At all ranges tested, the cross-wind deflection was reduced by the large amount of 25%, although the projectile according to the invention is heavier and has a lower muzzle velocity than the known projectile. The data in the table were determined in conventional manner by the known light-barrier method of measuring the air resistance coefficient and by conventional

calculations from the coefficient as obtained.

The previously-described small-arms ammunition and the corresponding jacketed projectile the special advantage that they can be used with most important weapons construction in use at present. The novel jacketed projectile profile does not require any changes in gun construction for use.

The use of the improved aerodynamic profile according to the invention is not restricted to jacketed projectiles. Projectiles made of solid material, owing to their high initial velocity, appear suitable for special applications, more particularly for small and hand arms.

List of references

- 1 = cartridge case.
- 2 = power charge
- 3 = jacket or projectile
- 4 = front part
- 5 = middle part
- 5a = portion of middle part 5
- 6 = rear end
- 7 = grooved portion
- 8 = open end of cartridge case 1
- 9 = edge of open end 8
- 10 = closed end of cartridge case 1
- 11 =
- 12 = front end
- 13 = inner, frusto-conical portion of end 6
- 14 = outer frusto-conical portion of end 6

- 15 = core of jacketed projectile
- 16 = cup
- 17 = cylindrical part of cup
- 18 = rounded part of cup
- 19 = area of cup near base
- 20 = crimp.



Claims

1. Small-arms ammunition, comprising an axially symmetrical projectile (3 to 7; 12), a cartridge case (1) with a powder charge (2) and a primer (11) disposed centrally with respect to the longitudinal axis thereof, the cartridge case being secured in a portion (7) between the flattened tip (12) of the projectile and its rear end (6), characterised in that the profile of the projectile (3 to 7; 12 to 14) is defined by a summation function

$$r(x) = r_1(x_1) + r_2(x_2)$$

in which the range of x_1 is given by

$$x_1 = \frac{h}{2} (1 - \cos a) - \frac{s}{2} (1 + \cos a),$$

in which h is an imaginary length of x_1 for $a = \pi$ up to an imaginary tip of the projectile (3 to 7; 12 to 14) and arc $\cos$

$$\frac{h-s}{h+s} \leq a \leq \pi.$$

and the associated values of r_1 are given by

$$r_1 = r_0 \sqrt{\frac{1}{\pi} \left(a - \frac{1}{2} \sin 2a \right)}$$

in which arc $\cos$

$$\frac{h-s}{h+s} \leq a \leq \pi$$

and in which the range of x_2 is defined by

$$x_2 > h$$



in which $r_2 = \text{const.} = r_0$, the imaginary tip of the projectile (3 to 7; 12) being remote by a distance $(-s)$ from the origin of a right-angled system of coordinates, the positive X-axis of which is an axis of symmetry and the Y-axis of which represents a direction of the radius r of the projectile and the actual tip (12) of the projectile (3 to 7; 12) is situated at the origin of the system of coordinates. (Fig. 2; Fig. 1).

2. Small-arms ammunition according to Claim 1, characterized in that the portion (7) for securing the cartridge sleeve (1) is displaced into the region of x_2 by a distance in the range of 0.1 to 0.5 r_0 from the place corresponding to an upper limiting value of x_1 (Fig. 2).

3. Small-arms ammunition according to claim 1 or 2, characterised in that a rear end (6) of the projectile (4 to 7, 12 to 14) comprises two substantially frusto-conical portions (13, 14), the imaginary apices of which lie on the axis of symmetry of the projectile, and the internal portion (13) with respect to the end has an angle of taper in the range from 5 to 10° and a length in the range from 0.5 to 2 r_0 and the external portion (14) with respect to the end has an angle of taper in the range of 60° and ends at a distance from the axis of symmetry of the projectile (Fig. 2).



4. Small-arms ammunition according to any of the preceding claims, characterised in that the projectile (3 to 7, 12 to 15) is a jacketed projectile having a jacket (3) made of clad alloyed steel in which a heavy-metal core (15) is inserted (Fig. 2; Fig. 1).

5. Small-arms ammunition according to claims 1 to 4, characterised in that between its ends (4, 6) the jacket (3) has a groove portion (7) for securing the jacket to the cartridge case (1) (Fig. 1).

6. A method of manufacturing an axially symmetrical jacketed projectile for small-arms ammunition according to claim 1, in which the cylindrical cup (16) rounded at the base is deep-drawn, characterised in that in a first step the pre-formed cup (16) is elongated during subsequent drawing without altering the thickness of the base and the angle of the internal taper is reduced, in a second step the cylindrical part of the projectile is drawn and a flash collar is formed at the end, the internal taper angle being further reduced, in a third step the tip of the projectile is pre-formed in a polished, smooth female die, in a fourth step the tip of the projectile is given its final shape in a second polished, smooth female die, in a fifth step the projectile is cut to its provisional length at the flash collar, in a sixth step a pre-formed heavy-metal core



is pressed in to the projectile, in a seventh step the rear part of the projectile is given a conical shape, in an eighth step the rear edge is crimped over the heavy-metal core, in a ninth step the rear end of the projectile is given its final shape and in a tenth step the projectile is pushed through a female calibrating die.

7. A method according to claim 6, characterised in that the first to the tenth steps are interlinked and carried out on a single progressive press.

8. Application of the method according to claims 6 or 7 for manufacturing a small-arms hard-lead core projectile (Fig. 2).