(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 354 210 B1**

(12) # EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: **08.12.93** (51) Int. Cl.5: **F42B 10/06**

(21) Application number: **88902175.4**

(22) Date of filing: **09.03.88**

(86) International application number:
PCT/GB88/00179

(87) International publication number:
WO 88/07169 (22.09.88 88/21)

(54) **TAIL FIN UNIT FOR A PROJECTILE.**

(30) Priority: **17.03.87 GB 8706250**

(43) Date of publication of application:
14.02.90 Bulletin 90/07

(45) Publication of the grant of the patent:
08.12.93 Bulletin 93/49

(84) Designated Contracting States:
DE FR GB IT NL SE

(56) References cited:
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(73) Proprietor: **The Secretary of State for Defence in Her Britannic Majesty's Government of the United Kingdom of Great Britain and Northern Ireland**
Whitehall
London SW1A 2HB(GB)

(72) Inventor: **SMITH, Stephen, George, Gladwell**
The Old Barn
Fullers Hill
Seal Sevenoaks, Kent TW15 0EN(GB)
Inventor: **WALKER, David, Howard**
5 Keston Gardens
Keston Kent BR7 6BL(GB)

(74) Representative: **Beckham, Robert William**
Defence Research Agency
Intellectual Property Department
DRA Farnborough
Farnborough, Hants. GU14 6TD (GB)

EP 0 354 210 B1

Description

This invention relates to a non-metallic tail fin for a subcalibre kinetic energy projectile, herein called a long rod projectile, as described in the pre-characterising part of claim 1 and conventionally fired with an associated surrounding discard sabot from a larger calibre gun so as to impart a supersonic velocity and thereby high kinetic energy to the projectile. Such projectiles are known from EP-A-0 174 082.

Long rod projectiles are known for their excellent penetrating power and are normally employed in direct fire mode, that is to say they are fired along a substantially flat trajectory, for attacking armoured targets which may range from relatively lightly-armoured personnel carriers, helicopters and aircraft to heavily-armoured battle tanks. A projectile of this type is usually fin stabilised, and comprises a dense, cylindrical penetrator having a tail fin unit attached to its rear end. The tail fin unit consists of a fin unit body member coaxially attached to the projectile, with a plurality of radially protrusive fins extending therefrom. In order to provide the required high penetration power, the body member is typified by an average density of at least 7gm cm^{-3}, more usually at least 15gm cm^{-3}, and a length-to-diameter ratio of at least 10:1.

The main purposes of a tail fin unit on a long rod projectile are to dampen out yaw imparted to the projectile at launch and thereafter stabilise the flight of the projectile to the target. However, in the fin-stabilised long rod projectile of the type herein defined, the fin unit also provides the projectile with an aerodynamically-induced rate of spin during its flight which is sufficient to even out any asymmetrical in-flight forces caused by manufacturing asymmetrics in the shape or balance of the projectile which would otherwise give rise to unacceptable inaccuracies at the target. This spin rate is typically 20-200 revolutions per second and usually represents only a small fraction of the rate of spin imparted to non-finned, spin-stabilised projectiles fired from guns (spin-rates, in the later type of projectile, of several hundred revolutions per second are typical). However, this spin rate must be greater than the spin rate at which the long rod projectile exhibits spin yaw resonance, which is a spin rate at which the yaw of the projectile builds up during its flight to the target.

In order to optimise the penetration and in-flight stability of a long rod projectile it is known to use tail fin units having lightweight metal fins of, for example, aluminium alloy. The light weight of these fins ensure that once fitted, the mass of the unit causes no significant rearward shift in the centre of gravity of the projectile. The static margin between the projectile's centre of gravity and centre of pressure is not, therefore, significantly reduced, which means that the stability of the projectile in flight is not unduly affected. An additional reason for using lightweight metal fins is that it ensures a high proportion of the overall mass of the projectile is concentrated in the penetrator.

The cost of producing lightweight metal tail fin units may be kept to a minimum by extruding each unit in one piece. The process of extrusion produces fins which are parallel to the extruding axis (which axis also defines the axis of the unit) and are of constant cross-sectional shape and area in keeping with the shape of the extrusion die. Further modification to the contour of the fins is therefore essential to ensure the units are capable of imparting spin to an in-flight projectile. This modification normally involves machining, at an acute angle to the axis of the unit, a leading or trailing edge chamfer on each fin which creates an asymmetric lateral force on each fin so as to transmit an axial torque to the projectile and thereby provide the necessary slow rate of spin. However, these chamfers are susceptible to damage during the launch of the projectile and its subsequent flight to the target, and this damage can cause variation in spin rate resulting in a catastrophic effect on flight performance.

Fin units of this type are subject to extremely high in-bore propellant flash temperatures and subsequent aerodynamic heating temperatures which can well exceed the melting point of a lightweight metal. Consequently such fin units must be protected from damage by the provision of a heat resistant or a heat absorbent coating to prevent distortion of the fin profile. One particular heat absorbent coating known for this purpose is described in GB1604865 and comprises a thin heat-cured, homogeneous layer of an epoxy resin which will ablate uniformly and consistently at the temperatures encountered, thereby ensuring continuously balanced maintenance of the fin profiles and constancy of spin rate.

Clearly it would be desirable to extend this ablative principle to a lighter-weight and more simply fabricated fin unit made entirely from a plastics material, but in order to withstand gun chamber pressures the plastics material would require reinforcement, resulting in a heterogeneous composite which would not ablate with sufficient uniformity to maintain a constant spin rate.

The present invention seeks to provide a lightweight, mouldable, reinforced plastics material fin unit having a profile which is less sensitive to uneven in-flight ablation so as to ensure a predetermined velocity-related spin rate throughout flight. The invention further seeks to employ controlled in-flight ablation to achieve a drag reduction during flight.

In accordance with claim 1 of the present specification a tail fin unit for a long rod projectile comprises an axisymmetric fin unit body member coaxially attachable to the projectile and having a plurality of radially protrusive fins, characterised in that the fin unit body and the fins comprise an integral plastics material moulding and the fins are each disposed as a helix of constant pitch around the longitudinal axis of the moulding.

The principal advantages of the present tail fin unit is that by the use of plastic helical fins of constant pitch to impart the necessary in-flight rate of spin to the projectile, any unequal in-flight ablation of the leading edges of these fins caused by aerodynamic heating will occur without detriment to the spin rate of the long rod projectile. Furthermore, the process of ablation can itself be turned to advantage because by an appropriate selection of plastics material, it can be used to bring about a significant reduction in the size (and hence surface area) of the fins as they burn away from their leading edges. The surface area hence size of the fins are normally selected to ensure they are large enough to perform their primary function of damping out yaw imparted to the projectile at launch. Thereafter, only a fraction of this surface area is required for the purpose of maintaining in-flight spin and stability, so that much of the surface area required at launch contributes to unwanted drag on the projectile once in flight. Controlled in-flight ablation from the leading edge can therefore have the benefit of reducing drag as the flight of the projectile proceeds.

The plastics material is preferably a polymer material comprising a thermoplastic or a thermoset resin composition. Suitable thermoset compositions include thermoset polyesters and cured epoxy resins, whereas suitable thermoplastics include thermoplastic polyesters, polyamides, thermoplastic liquid crystal polymers, polycarbonates, polysulphones, polyethersulphones, polyetherimides, and polyetherketones (PEEK). The material may be filled with reinforcing materials comprised by randomly disposed, chopped strands of glass, aramid or carbon fibres. The fibres preferably constitute from 2 to 45% by volume of the plastics material and preferably have an average length of up to 25mm, more preferably of from 0.25mm to 25mm.

Any suitable method of moulding known to those skilled in the art may be employed in the manufacture of the present tail fin unit, but injection moulding is preferred. The rear end of the penetrator is preferably encased within an axial recess within the fin unit body member to provide the necessary attachment, and preferably includes one or more radial protrusions or indentations to prevent relative axial and rotational movement of the penetrator with respect to the tail fin unit.

The body member preferably has an average density of at least 7gm cm^{-3}, more preferably at least 15gm cm^{-3}, and preferably has a length-to-diameter ratio of at least 10:1.

The present tail fin unit is, in accordance with claim 14 of this specification, conveniently manufactured by the steps of (a) centrally locating one end of a cylindrical fin unit holding member in a removable tail fin unit mould to close said mould, (b) moulding the tail fin unit onto the said one end in the mould, and (c) withdrawing the moulded tail fin unit from the mould. Step (b) preferably comprises the process of injection moulding. It is one further advantage of the present tail fin unit that step (c) may be accomplished by axially twisting and separating the mould and holding member relative to one another in such a manner that the moulded fin unit follows a helical path through the mould which is in the same direction and of the same pitch as the fins. In this way, the moulded fin unit may be extracted from the mould without first dismantling those portions of the mould adjacent the fins, which thereby provides a simple and easily automated fin unit withdrawal step.

The fin unit moulding is preferably directly attached to the rear end of the long rod projectile during the moulding process. Alternativly, the said one end of the holding member is screw threaded to allow subsequent rotational detachment of the holding member from the moulded tail fin unit.

Embodiments of the tail fin units according to this invention and of long rod projectiles incorporating same will now be described by way of example only with reference to the accompanying drawings of which

Figure 1 is a partial side elevation of a first embodiment, showing a long rod projectile having a helical fin unit attached to its rear end,

Figure 2 is a cross-section view of the projectile of Figure 1 taken along line I-I,

Figure 3 is a longitudinal section of the projectile of Figure 2 taken along line II-II, and

Figure 4 is a longitudinal section, similar to that shown in Figure 3, of a second embodiment which is taken through the rear portion of a long rod projectile having a helical fin unit screwed onto its rear end.

The fin unit 10 depicted in Figures 1, 2 and 3 comprises a central cylinder 12 having an axial recess 14 in its forward end and having six radially protrusive fins 16 each extending along the length of the cylinder 12 as a right-handed helix of 20 metre pitch. Each fin 16 widens at the root 18 where it adjoins the cylinder 12 and tapers down towards the cylinder 12 at its leading edge 20. The taper on each leading edge 20 is symmetrically rounded to ensure that the impact of each leading edge 20 with axial air flow past the fin unit 10 imparts no axial torque thereto. The fin tips 22 are rounded and have a total angle A of twist from end to end of the unit which, on a unit length of 100mm, is 1.8°. The fin unit 10 is shown attached to the rear end 24 of a cylindrical penetrator 26 made of tungsten alloy. The penetrator 26 has a nose portion 28 at its forward end and has a length-to-diameter ratio of 12:1. The attachment between the fin unit 10 and rear end 24 is provided by knurling 30 on the encased cylindrical surface of the rear end 24, which engages with the interior of the recess 14.

The unit 10 is manufactured by injecting a molten thermosetting composition or thermoplastic material incorporating chopped reinforcing fibres of Kevlar (Registered Trade Mark) aramid into a removable fin unit mould (not shown) within which the knurled rear end 24 of the projectile body 26 has been centrally located to close the mould. A process of transfer moulding may alternatively be employed. Examples of aramid-containing thermosetting compositions employed were the moulding compounds E20328, which is an epoxy resin moulding compound incorporating chopped Kevlar fibres which is manufactured by the Fiberlite Corporation of Winona, Minnesota, USA and Freemix 43-2067, which is a thermosetting polyester moulding compound incorporating about 5% by weight of 6mm chopped Kevlar fibres and supplied by Freeman Polymers Division of PO Box 8, Ellesmere Port, South Wirral, England. Thereafter the fin unit moulding is set in situ either by cooling (in the case of a thermoplastic) or heat curing (in the case of a thermosetting composition), and the fin unit mould removed. The removal operation is preferably accomplished by axially twisting and separating the mould and projectile body 26 relative to one another in such a manner that the moulded tail fin unit 10 follows a helical path through the mould in the same direction and of the same pitch as the fins 16. In this way, the moulded unit 10 may be extracted from the mould without dismantling those portions of the mould surrounding the fins 16, so that high production rates of fin units are made possible using only one or a small number of moulds. Composite mouldings of this type have been found capable of resisting gun chamber pressures of up to 4000kg cm^{-2}.

In the second embodiment (see Figure 4), the basic structure is very similar to that described with reference to Figures 1 to 3 and, accordingly, the same reference numerals as used in Figures 1 to 3 but with the prefix "1" have been used in Figure 4.

The fin unit 110 depicted in Figure 4 is identical to that illustrated in Figures 1, 2 and 3 except that the recess 114 has an axially threaded portion 134 which engages with a cooperating threaded portion 136 on the rear end 124 of a second cylindrical projectile body 126. The thread on the fin unit 110 may be right-handed or left-handed according to the type of gun from which the projectile is to be fired. Manufacture of the fin unit 110 is, again, identical to the manufacture of the fin unit 10 except that in the case of the fin unit 110, a cylindrical fin unit holder (not shown) with a threaded portion on its rear end may be used in place of the projectile body member 126 itself. The threaded portion on the holder is identical in shape and size to the threaded portion 136 on the projectile body 126. This allows for separate storage of the moulded fin unit 110 once it has been rotationally detached from the holder, so that the fin unit 110 may then be attached at a later time to the threaded portion 136 on projectile body 126.

In use, each of the fin units 10, 110 is subject to erosion by burning propellant gases during launch, and thereafter to in-flight ablation at the leading edges 20, 120 of the fins 16, 116 due to aerodynamic heating. Ablation may not occur evenly but because the fins 16, 116 are of constant pitch, any loss of material from their leading edges 20, 120 will occur without detriment to the spin rate of the projectile. Since erosion through ablation will reduce the size hence surface area of the fins, any significant ablation will also have the effect of reducing the net drag of the projectile during its flight once the fins have performed their primary function of damping out yaw imparted at launch.

Claims

1. A long rod projectile comprising a cylindrical penetrator (26,126) having a rear end (24,124) coaxially attached to a tail fin unit (10,110) which comprises an axisymmetric fin unit body member (12,112) having a plurality of radially protrusive fins (16,116), characterised in that the fin unit body (12,112) and the fins (16,116) comprise an integral plastics material moulding and the fins (16, 116) are each disposed as a helix of constant pitch around the longitudinal axis of the moulding.

2. A long rod projectile according to claim 1 characterised in that the plastics material comprises either a thermoset composition or a thermoplastic.

3. A long rod projectile according to claim 2 characterised in that the thermoset composition comprises a cured epoxy resin or a thermoset polyester.

4. A long rod projectile according to claim 2 characterised in that the thermoplastic is selet-

ed from the group consisting of thermoplastic polyesters, polyamides, thermoplastic liquid crystal polymers, polycarbonates, polysulphones, polyethersulphones, polyetherimides, and polyetherketones (PEEK).

5. A long rod projectile according to claim 1 characterised in that the plastics material contains chopped fibres of a reinforcing material.

6. A long rod projectile according to claim 5 characterised in that the plastics material contains from 2% to 45% by volume of the reinforcing material.

7. A long rod projectile according to claim 5 characterised in that the average length of the chopped fibres is from 0.25mm to 25mm.

8. A long rod projectile according to any one of claims 5 to 7 characterised in that the reinforcing material is an aramid fibre.

9. A long rod projectile according to claim 1 characterised in that the moulding is manufactured by an injection moulding process.

10. A long rod projectile according to any preceding claim characterised in that the rear end (24,124) of the penetrator (26,126) is encased within an axial recess (14,114) in the fin unit body member (12,112).

11. A long rod projectile according to claim 10 characterised in that the encased rear end (24,124) of the penetrator (26,126) is provided with one or more radial protrusions or indentations (30,136) to prevent relative axial and rotational movement of the penetrator (26,126) with respect to the tail fin unit (10,110).

12. A long rod projectile according to claim 11 characterised in that the cylindrical surface of the encased rear end (24) of the penetrator (26) is provided with knurling (30).

13. A long rod projectile according to claim 10 characterised in that the axial recess (14) in the fin unit body member (110) and the rear end (124) of the penetrator (126) are each provided with co-operating screw threaded portions (134,136).

14. A process for manufacturing a long rod projectile according to claim 1 including the steps of (a) centrally locating one end of a cylindrical fin unit holding member in a removable tail fin unit mould to close said mould, (b) moulding the tail fin unit onto the said one end in the mould, and (c) removing the mould from the moulded tail fin unit.

15. A process according to claim 14 characterised in that step (c) is accomplished by axially twisting and separating the mould and holding member relative to one another so that the moulded tail fin unit follows a helical path through the mould in the same direction and of the same pitch as the fins.

16. A process according to claim 14 characterised in that the said one end comprises the rear end of the cylindrical penetrator.

17. A process according to claim 14 characterised in that the said one end of the holding member is screw threaded to allow rotational detachment of the holding member from the moulded tail fin unit.

Patentansprüche

1. Langstabprojektil mit einem zylindrischen Penetrationskörper (26, 126), dessen hinteres Ende (24, 124) koaxial an einer Heckflosseneinheit (10, 110) befestigt ist, die einen axialsymmetrischen Flosseneinheitskörper (12, 112) mit mehreren radial hervorstehenden Flossen (16, 116) umfaßt,
dadurch gekennzeichnet,
daß der Flosseneinheitskörper (12, 112) und die Flossen (16, 116) einen einstückigen Formkörper aus einem Kunststoffmaterial darstellen, und die Flossen (16, 116) jeweils als Helix mit einer konstanten Steigung um die Längsachse des Formkörpers herum angeordnet sind.

2. Langstabprojektil gemäß Anspruch 1, **dadurch gekennzeichnet**, daß das Kunststoffmaterial eine wärmegehärtete oder eine thermoplastische Zusammensetzung umfaßt.

3. Langstabprojektil gemäß Anspruch 2, **dadurch gekennzeichnet**, daß die wärmegehärtete Zusammensetzung ein gehärtetes Epoxyharz oder einen wärmegehärteten Polyester umfaßt.

4. Langstabprojektil gemäß Anspruch 2, **dadurch gekennzeichnet**, daß der thermoplastische Kunststoff unter thermoplastischen Polyestern, Polyamiden, thermoplastischen Flüssigkristall-Polymeren, Polycarbonaten, Polysulfonen, Polyethersulfonen, Polyetherimiden und Polyetherketonen (PEEK) ausgewählt ist.

5. Langstabprojektil gemäß Anspruch 1, **dadurch gekennzeichnet**, daß das Kunststoffmaterial gehäckselte Fasern eines Verstärkungsmaterials enthält.

6. Langstabprojektil gemäß Anspruch 5, **dadurch gekennzeichnet**, daß das Kunststoffmaterial 2 bis 45 Volumen-% Verstärkungsmaterial enthält.

7. Langstabprojektil gemäß Anspruch 5, **dadurch gekennzeichnet**, daß die mittlere Länge der gehäckselten Fasern 0,25 mm bis 25 mm beträgt.

8. Langstabprojektil gemäß einem der Ansprüche 5 bis 7, **dadurch gekennzeichnet**, daß das Verstärkungsmaterial Aramidfasern sind.

9. Langstabprojektil gemäß Anspruch 1, **dadurch gekennzeichnet**, daß der Formkörper durch Spritzgießen hergestellt ist.

10. Langstabprojektil gemäß einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet**, daß das hintere Ende (24, 124) des Penetrationskörpers (26, 126) von einer axialen Ausnehmung (14, 114) im Flosseneinheitskörper (12, 112) umschlossen ist.

11. Langstabprojektil gemäß Anspruch 10, **dadurch gekennzeichnet**, daß das umschlossene hintere Ende (24, 124) des Penetrationskörpers (26, 126) mit einem oder mehreren radialen Vorsprüngen oder Vertiefungen (30, 136) versehen ist, um eine axiale sowie eine Drehbewegung des Penetrationskörpers (26, 126) relativ zur Heckflosseneinheit (10, 110) zu verhindern.

12. Langstabprojektil gemäß Anspruch 11, **dadurch gekennzeichnet**, daß die zylindrische Oberfläche des umschlossenen hinteren Endes (24) des Penetrationskörpers mit einer Rändelung (30) versehen ist.

13. Langstabprojektil gemäß Anspruch 10, **dadurch gekennzeichnet**, daß die axiale Ausnehmung (14) in der Heckflosseneinheit (110) und das hintere Ende (124) des Penetrationskörpers (126) mit zusammmenwirkenden Schraubengewindeabschnitten (134, 136) versehen sind.

14. Verfahren zum Herstellen eines Langstabprojektils gemäß Anspruch 1, das die folgenden Schritte umfaßt:

(a) Zentrales Anordnen eines Endes eines Halteelements für eine zylindrische Flosseneinheit in einer abnehmbaren Heckflosseneinheitsform und Schließen dieser Form.
(b) Ausformen der Heckflosseneinheit auf dem einen Ende in der Form und
(c) Abnehmen der Form von der ausgeformten Heckflosseneinheit.

15. Verfahren gemäß Anspruch 14**, dadurch gekennzeichnet**, daß der Schritt (c) durch axiales Verdrehen und Trennen der Form und des Halteelements relativ zueinander derart ausgeführt wird, daß die geformte Heckflosseneinheit einer schraubenförmigen Bahn in gleicher Richtung und mit gleicher Steigung wie bei den Flossen durch die Form hindurch folgt.

16. Verfahren gemäß Anspruch 14, **dadurch gekennzeichnet**, daß das eine Ende das hintere Ende des zylindrischen Penetrationskörpers umfaßt.

17. Verfahren gemäß Anspruch 14, **dadurch gekennzeichnet**, daß das eine Ende des Halteelements mit einem Schraubengewinde versehen ist, das ein Lösen des Halteelements von der ausgeformten Heckflosseneinheit durch Drehen ermöglicht.

Revendications

1. Projectile à barre allongée, comprenant un organe cylindrique de pénétration (26, 126) ayant une extrémité arrière (24, 124) fixée coaxialement à un ensemble à empennage (10, 110) qui comporte un corps (12, 112) à symétrie axiale de l'ensemble à empennage, ayant plusieurs ailettes qui dépassent radialement (16, 116), caractérisé en ce que le corps (12, 112) et les ailettes (16, 116) sont formés d'un moulage de matière plastique en une seule pièce, et les ailettes (16, 116) sont disposées chacune suivant une hélice de pas constant autour de l'axe longitudinal du moulage.

2. Projectile à barre allongée selon la revendication 1, caractérisé en ce que la matière plastique est une composition thermodurcissable ou une matière thermoplastique.

3. Projectile à barre allongée selon la revendication 2, caractérisé en ce que la composition thermodurcissable est une résine époxyde durcie ou un polyester durci.

4. Projectile à barre allongée selon la revendication 2, caractérisé en ce que la matière thermoplastique est choisie dans le groupe qui comprend les polyesters thermoplastiques, les polyamides thermoplastiques, les polymères à cristaux liquides thermoplastiques, les polycarbonates, les polysulfones, les polyéthersulfones, les polyétherimides et les polyéthercétones (PEEK).

5. Projectile à barre allongée selon la revendication 1, caractérisé en ce que la matière plastique contient des fibres coupées d'une matière d'armature.

6. Projectile à barre allongée selon la revendication 5, caractérisé en ce que la matière plastique contient 2 à 45 % en volume de matière d'armature.

7. Projectile à barre allongée selon la revendication 5, caractérisé en ce que la longueur moyenne des fibres coupées est comprise entre 0,25 et 25 mm.

8. Projectile à barre allongée selon l'une quelconque des revendications 5 à 7, caractérisé en ce que la matière d'armature est formée de fibres d'aramide.

9. Projectile à barre allongée selon la revendication 1, caractérisé en ce que le moulage est fabriqué par une opération de moulage par injection.

10. Projectile à barre allongée selon l'une quelconque des revendications précédentes, caractérisé en ce que l'extrémité arrière (24, 124) de l'organe de pénétration (26, 126) est enrobée dans une cavité axiale (14, 114) du corps (12, 112) de l'ensemble à ailettes.

11. Projectile à barre allongée selon la revendication 10, caractérisé en ce que l'extrémité arrière enrobée (24, 124) de l'organe de pénétration (26, 126) a une ou plusieurs saillies ou cavités radiales (30, 136) destinées à empêcher un déplacement relatif axial et en rotation de l'organe de pénétration (26, 126) et de l'ensemble à empennage (10, 110).

12. Projectile à barre allongée selon la revendication 11, caractérisé en ce que la surface cylindrique de l'extrémité arrière enrobée (24) de l'organe (26) de pénétration porte un moletage (30).

13. Projectile à barre allongée selon la revendication 10, caractérisé en ce que la cavité axiale (14) du corps (110) et l'extrémité arrière (124) de l'organe (126) de pénétration ont des parties à filet qui peuvent coopérer (134, 136).

14. Procédé de fabrication d'un projectile à barre allongée selon la revendication 1, comprenant les étapes suivantes : (a) le positionnement central d'une première extrémité d'un organe de maintien d'un ensemble cylindrique à ailettes dans un moule d'ensemble à empennage afin que le moule soit fermé, (b) le moulage de l'ensemble à empennage sur la première extrémité dans le moule, et (c) l'extraction de l'ensemble moulé à empennage du moule.

15. Procédé selon la revendication 14, caractérisé en ce que l'étape (c) est réalisée par torsion axiale et séparation du moule et de l'organe de maintien l'un de l'autre afin que l'ensemble moulé à empennage suive un trajet hélicoïdal dans le moule, dans le même sens que les ailettes et avec le même pas.

16. Procédé selon la revendication 14, caractérisé en ce que la première extrémité est l'extrémité arrière de l'organe cylindrique de pénétration.

17. Procédé selon la revendication 14, caractérisé en ce que la première extrémité de l'organe de maintien est filetée afin qu'elle permette la séparation par rotation de l'organe de maintien et de l'ensemble moulé à empennage.

Fig. 1.

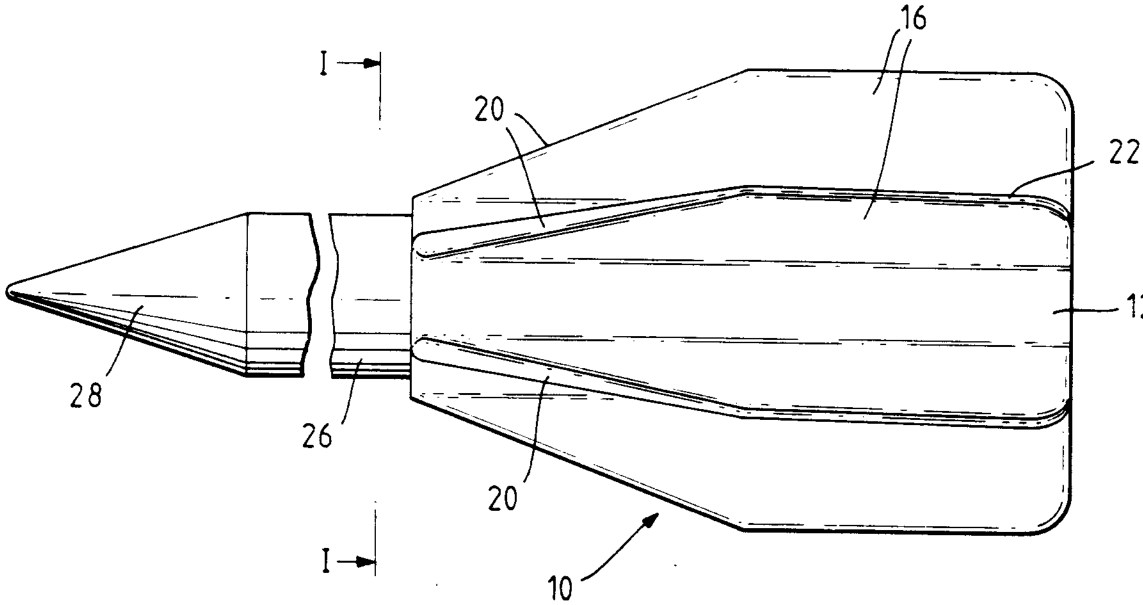

Fig. 2.

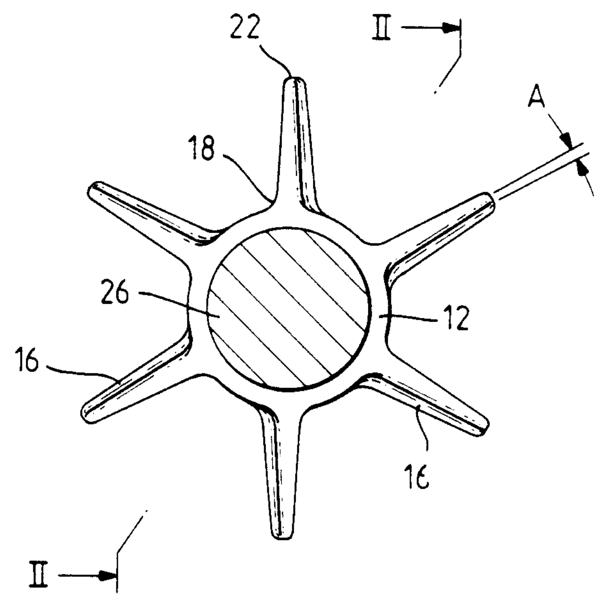

Fig. 3.

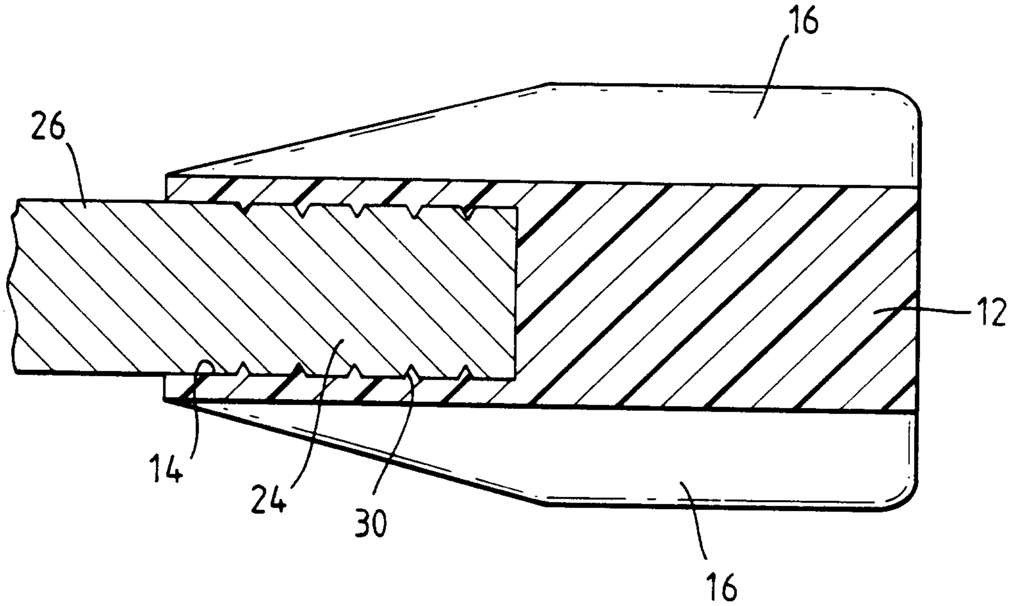

Fig. 4.