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(54) A method and an apparatus for determining the flight distance covered by a projectile.

(57) The present invention relates to a method and an apparatus (1) for continuously measuring the flight distance covered by a projectile, with the aid of an accelerometer (1) which exclusively measures the retardation acting on the projectile on each separate occasion.

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TECHNICAL FIELD

The present invention relates to a method of continuously measuring the flight distance covered by projectiles such as different types of shells etc., and an apparatus designed in accordance therewith. According to the present invention, the flight distance of the relevant projectile is determined on each separate occasion using exclusively its retardation as a point of departure. It will hereby be possible to track the flight path of the projectile along its ballistic trajectory and, on each separate occasion, to determine its position in relation to a predetermined target. The present invention may therefore be utilized to control the arming of a projectile.

The present invention also includes a sensor designed in accordance therewith whose substantial resilience and slight space requirements render it extremely well suited for incorporation into barrel ammunition, also including small-calibre such ammunition.

BACKGROUND ART

A shell which is discharged experiences what may be described as a shock impulse on firing of the order of magnitude of 10^5 g and thereafter solely a retardation caused by air resistance. Conventional accelerometers are therefore unsuitable for use in barrel ammunition.

In accordance with the present invention, it has now been conceived to utilize this retardation for range determination and, consequently, the present invention includes a sensor or accelerometer adapted exclusively for determination of negative acceleration levels. The sensor according to the present invention is thus prevented from moving against the flight direction of the projectile, so that it will be capable of withstanding the mechanical stresses during the firing cycle.

As a result of this technical solution, sufficient accuracy will be achieved in the distance measurement without requiring extreme resolutions in the signal processing of the system.

Hence, the present invention may be described as comprising a method and an apparatus for continuously determining the flight distance covered on each separate occasion along the ballistic trajectory of projectiles without inherent propulsion. According to the present invention, this is effected completely within the projectile by internal signal processing on the basis of the measured value of the initial retardation of the projectile and a continuous follow-up of its progressive retardation.

The sensor or accelerometer utilized according to the present invention should thus be blocked in the acceleration direction and only permitted to move towards the flight direction, i.e. the direction in which it is influenced on retardation. This is achieved in that it rests against a reference plane which prevents outward flexing of the beam of the accelerator during the firing phase. By thus utilizing an accelerometer which measures exclusively the retardation and which may therefore be given a considerably smaller measurement zone than an accelerometer which also measures the acceleration, the degree of measurement accuracy can be kept extremely high.

If the accelerometer is liquid-damped, there can be formed - in one or both of the mutually abutting interfaces between the accelerometer and the supporting surface - a pattern which reduces the capillary effect between these interfaces.

In order to ensure that the accelerometer survives possible retardation transients exceeding those levels which the accelerometer is to measure and to which the shell is subjected in the measurement direction on firing, the sensor may be provided with an overload guard which permits the accelerometer to move in an adapted piece in this direction before the overload guard is touched. Relevant retardation transients may for example be a consequence of the compression to which at least shells of smaller calibre are exposed during the acceleration phase proper. The overload guard, which of course must be placed so that the pertinent acceleration levels of interest can be measured unimpeded during flight, may be produced from the same material as the blocking arrangement of the sensor according to the present invention in the flight direction of the projectile, or from the same material as the sensor itself such as for example silicon or glass.

Utilizing the present invention, it is possible, i.a., to produce arming systems for artillery shells which relieve the gun crew from the duty of programming in each individual case the arming of the shells, in view of the loading gear of the gun, the strength of the charge, the powder temperature etc. Instead, the arming of the projectile will be dependent in each individual case upon the relationship of the relevant flight distance to a preselected reference range. Those error sources which may principally become pertinent in connection with the present invention depend upon the prevailing atmospheric conditions in the form of air pressure and winds. However, these do not give greater error margins than can be acceptable and the values obtained according to the present invention may be expected to be considerably better than those in existing systems.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

The nature of the present invention and its aspects will be more readily understood from the following brief description of the accompanying Drawings, and discussion relating thereto.

In the accompanying Drawings:

Fig. 1 is a plan view of the accelerometer;

Fig. 2 is a section taken along the section line II-II in Fig. 1;

Fig. 2 b is a section through an accelerometer with an overload guard in the measurement direction;

Fig. 3 is a connection diagram for the measurement circuit included in the accelerometer; and

Fig. 4 is a block diagram of the signal processing which leads to the desired value of the covered flight distance at each separate point in time.

DESCRIPTION OF PREFERRED EMBODIMENT

The accelerometer or sensor 1 shown in Figs. 1-2 is made of silicon and fundamentally consists of a flexible beam 2 which bends as a function of the applied acceleration which, in this case, is negative - i.e. a retardation. In order to amplify this behaviour, the outer, free end of the beam 2 is designed as a so-called seismic mass 3. The arrow F indicates the flight direction of the shell in which the sensor 1 is intended to be employed.

The movement (flexing) of the beam initiated by the acceleration (the retardation) is recorded by means of two strain-sensitive piezo resistors 4 and 5 placed in the weakest portion of the beam.

Two further corresponding resistors 6 and 7 are disposed on that portion of the sensor which is not affected by the bending or flexing of the beam on retardation (negative acceleration) acting on the shell. These totally four resistors 4-7 are coupled in a conventional measurement bridge (a Wheatstone bridge) with open earth so as to permit offset compensation of the sensor (see Fig. 3).

Figs. 2 a and b show where the sensor is permanently connected, for example glued, to the supporting surface 8, namely along the surfaces 9 and 10. Between the seismic mass 3 and the supporting surface 8 of the accelerometer, there has been marked what appears to be a narrow gap 11. However, this marking 11 should only be interpreted such that the seismic mass is supported there but is free to move away from the supporting surface 8.

In order to prevent the seismic mass 3 and the beam 2 from moving during the firing phase, the sensor 1 rests on a supporting surface 8. The supporting surface 8 may be manufactured from the same material as the sensor or from other material of sufficiently slight elasticity and flexibility.

The distance covered by the shell is calculated in the signal processing electronics whose fundamental construction is apparent from Fig. 4. The initial value of the retardation signal is sampled in order to calculate therefrom the discharge velocity, i.e. vo. In addition, the retardation is integrated twice. The discharge velocity is integrated so as to obtain a covered distance without taking into account the retardation caused by air resistance. From this signal, the double-integrated retardation signal caused by the air resistance is subtracted in order, by such means, to obtain the true distance flown along the ballistic trajectory of the projectile. Thereafter, comparison may be made between this signal and a predetermined reference range in order, at any given distance flown, to permit an event to occur inside the shell, for example arming.

The following abbreviations are employed in the block diagram of Fig. 4:

acc measured acceleration (i.e. retardation)

a_o initial retardation, i.e. the value which is obtained when the shell departs from the gun barrel or tube.

Since the discharge velocity of the shell is in square dependence upon the initial retardation a_o, the $\sqrt{}$ of the block diagram designates that operation which gives the value for v_o.

An integration gives $v_o t$, i.e. that flight distance which would have been achieved if the shell had not been affected by air resistance. The double integral of the measured retardation gives the air resistance ratio which, together with $v_o t$, gives a value of the flown distance s(t) and s_{ref} marks that comparative value which is to determine when any particular function such as arming, initiation etc. is to take place, i.e. as long as $s(t) < s_{ref}$, nothing will happen.

Thus, the inventive concept as herein disclosed is exclusively to utilize the retardation for distance determination, and to utilize an accelerometer adapted for these negative acceleration levels. The accelerometer according to the present invention is prevented from moving in a direction opposed to the flight direction of the shell during the firing phase so as not to fail on application of this impact loading. As a result of this solution, there will be obtained sufficient accuracy in the distance measurement without requiring extreme resolutions of the components of the system.

Fig. 2 b shows an accelerometer corresponding to that of Fig. 2 a, but in Fig. 2 b, the original sensor according to the present invention has been supplemented with an overload guard disposed in the measurement direction, i.e. in the flight direction of the pertinent projectile ahead of the seismic mass 3 of the sensor. This overload guard is designed so as to permit the seismic mass 3 of the sensor to move sufficiently in the measurement direction for an unimpeded determination of the acceleration levels of interest (i.e. the actual retardation) during the flight of the projectile, but prevents such overloads of the measurement system as may be caused by possible acceleration transients in the firing phase proper. The overload guard may suitably be manufactured from silicon, glass or other material possessing corresponding properties.

As has already been mentioned, it is possible using liquid-damped accelerometers of the type relevant here to reduce the capillary effect between the moving part of the accelerometer and the supporting surface by forming a pattern in one or both of the mutually abutting interfaces, i.e. the surfaces on either side of the contact surface marking 8.

The present invention should not be considered as restricted to that described above and shown on the drawings, many modifications being conceivable without departing from the spirit and scope of the appended claims.

Claims

1. A method of continuously determining the flight distance covered along the ballistic trajectory of projectiles without inherent propulsion, **characterized in that** this is effected wholly within the projectile by internal signal processing on the basis of the measured value of the initial retardation of the projectile and a continuous follow-up of its progressive retardation.

2. The method as claimed in Claim 1, **characterized in that** the retardation acting on the projectile is determined with the aid of a sensor (accelerometer) which is blocked from moving in a direction opposed to the flight direction of the projectile but is freely movable in the opposite direction.

3. The method as claimed in Claim 2, **characterized in that** the retardation acting on the projectile and measured by means of the sensor is utilized to continually calculate the flight distance of the projectile which is continuously compared with a predetermined flight distance in order, when these two flight distances correspond, to actuate a predetermined activity such as an arming procedure.

4. The method as claimed in Claim 2, **characterized in that** the initial or start radiation measured by means of the sensor is utilised for calculating the discharge velocity (v_o) of the projectile in the form of a root function of the first-mentioned.

5. A sensor (1) for integration in projectiles and intended for measuring both the initial retardation of said projectile and its progressive retardation in accordance with the method as claimed in any one of Claims 1-4, of the type which includes a movable so-called seismic mass (3) whose movement in relation to the rest of the sensor (1) is read off by means of strain-sensitive piezo resistors (4, 5), **characterized in that** the movement of said seismic mass (3) is blocked (8) in a direction opposed to the direction of movement of the projectile, but free in the opposite direction.

6. The sensor as claimed in Claim 5, **characterized in that** it is made from silicon and designed with a flexible beam (2) in which the seismic mass (3) is included, the flexing or bending of the beam (2) being read off by means of piezo resistors (4, 5) placed flush with the weakest portion of the beam, and the blocking of said seismic mass (3) in the opposite direction in relation to the flight direction of the projectile (F) consisting of a fixed supporting surface (8).

7. The sensor (1) as claimed in any one of Claims 5 or 6, **characterized in that** when the sensor (1) is liquid-damped, there has been formed, in at least one of the mutually abutting surfaces (11) in the starting position, a pattern which reduces the capillary effect between them.

8. The sensor (1) as claimed in any one or more of Claims 4-7, **characterized in that** it includes an overload guard (12) which, in the flight direction of each respective projectile, prevents the seismic mass (3) of the sensor (1) from moving more than that which corresponds to its intended measurement zone in this direction.

9. The sensor (1) as claimed in Claim 8, **characterized in that** the overload guard (12) consists of a fixed supporting surface disposed at an adapted distance from the seismic mass (3) of the sensor (1).

10. The sensor (1) as claimed in Claim 9, **characterized in that** its overload guard (12) is manufactured from silicon or glass.

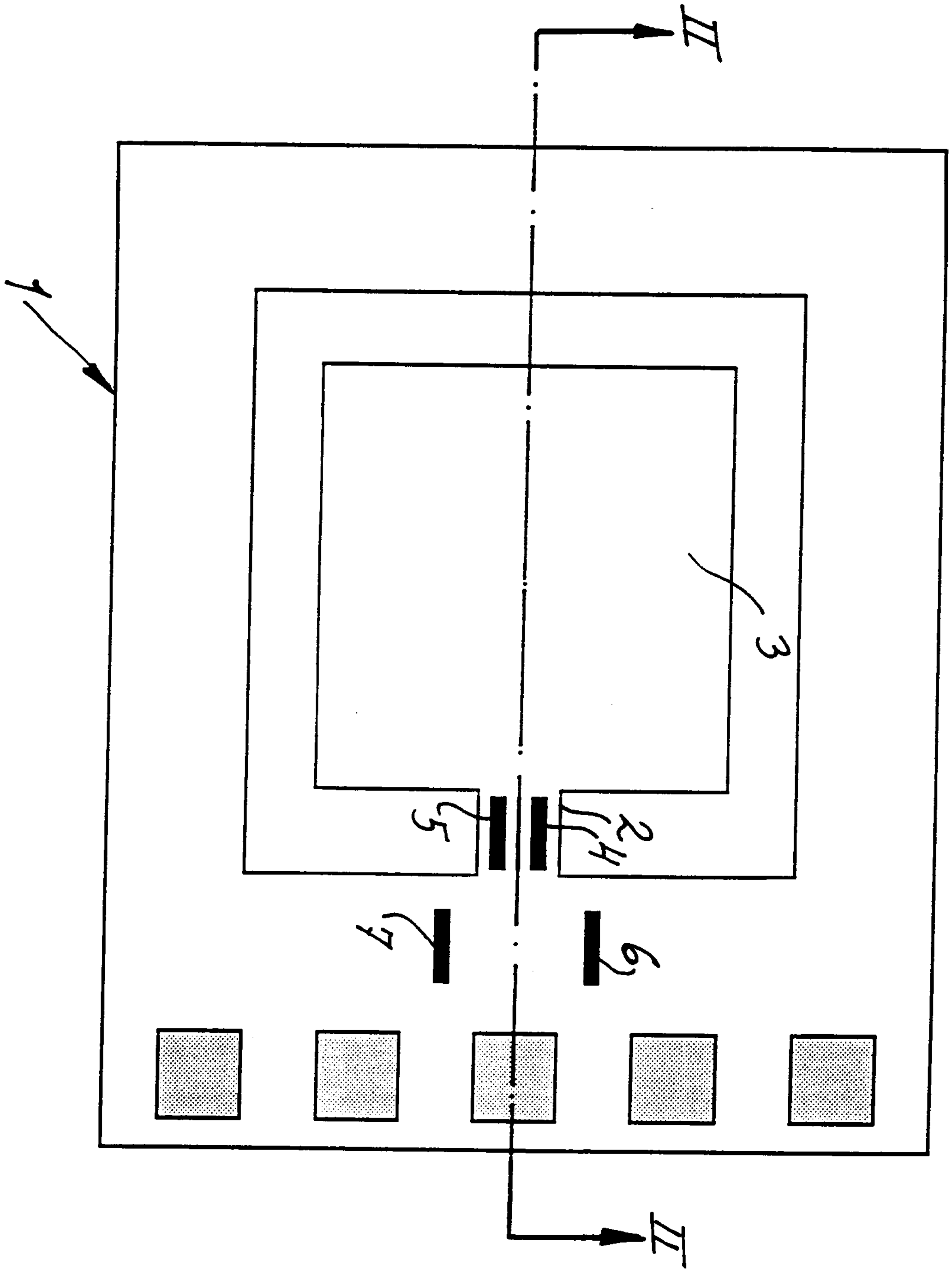

Fig. 1

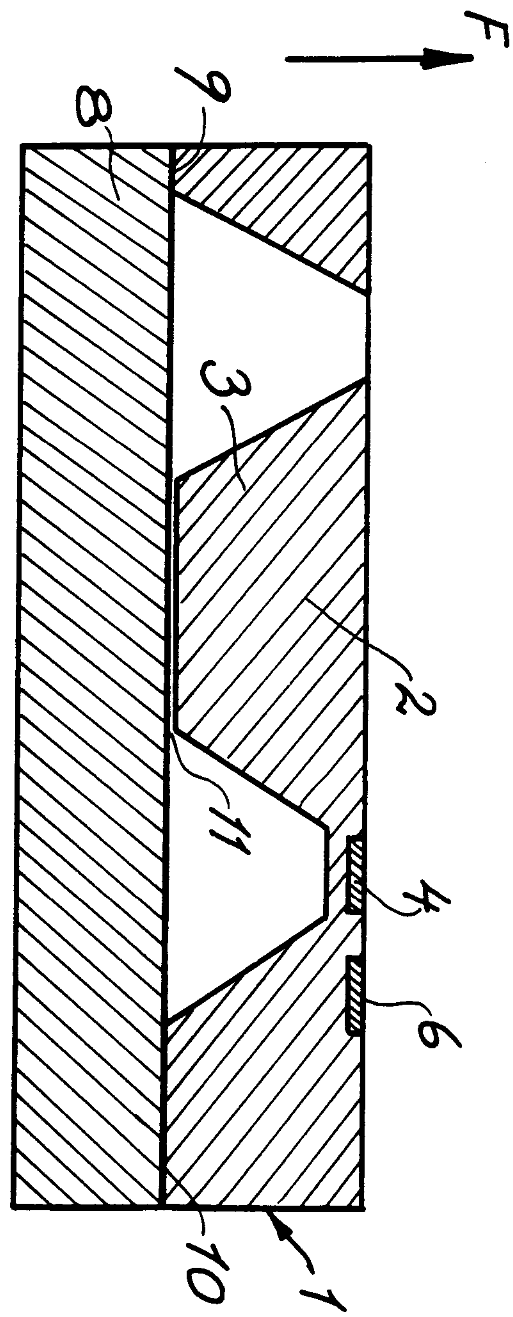

Fig. 2a

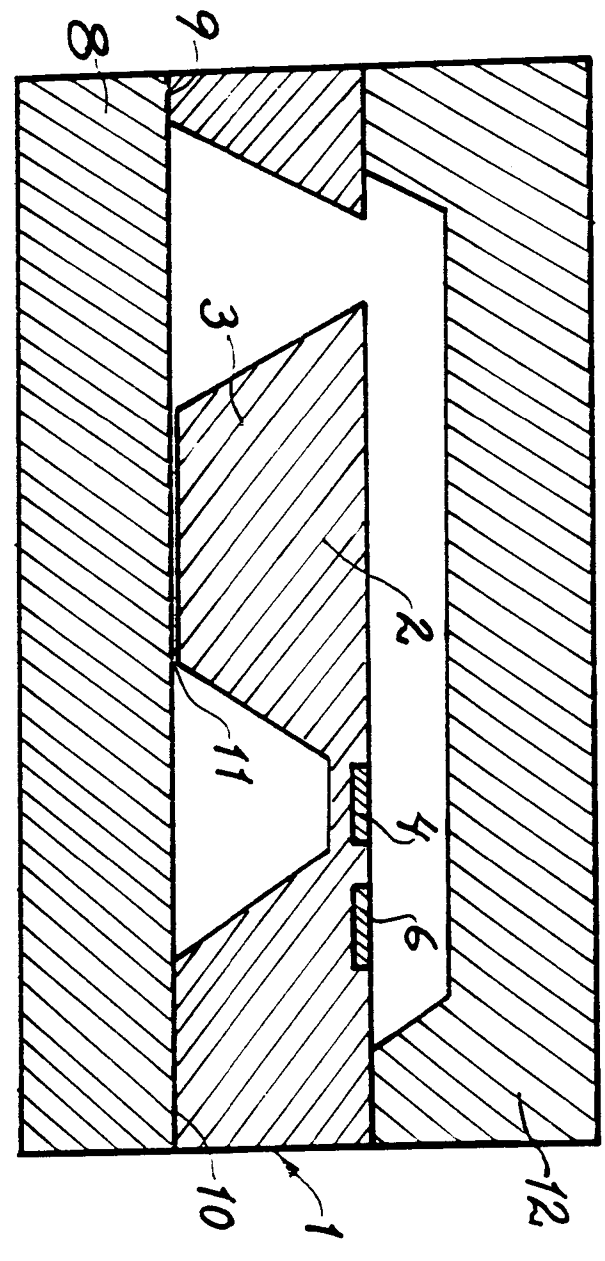

Fig. 2b

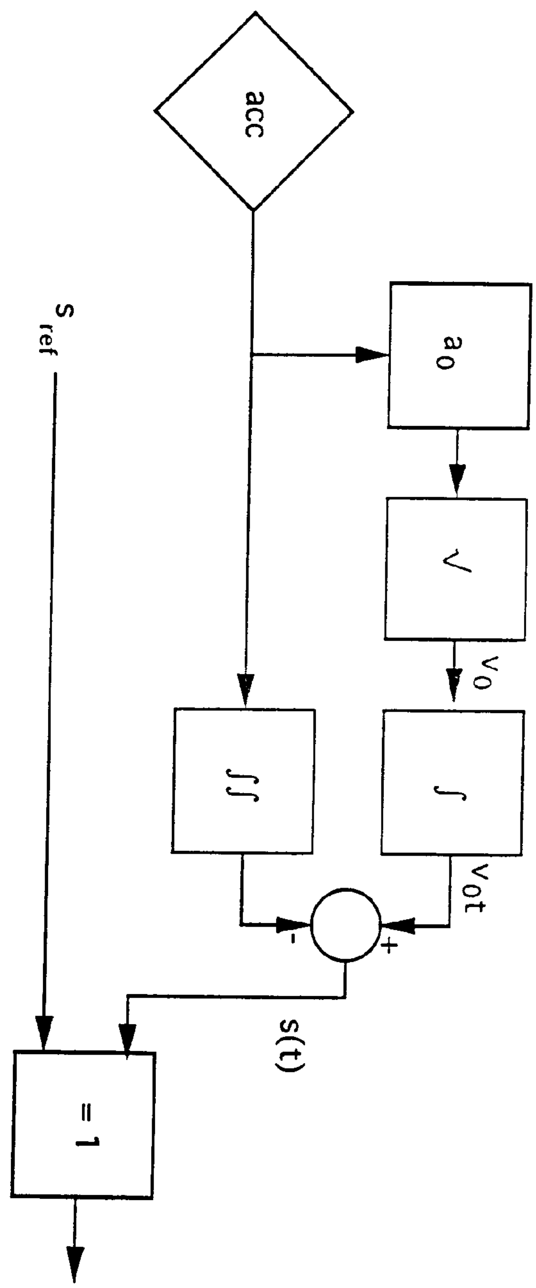

Fig. 4

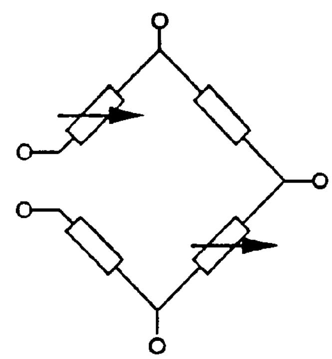

Fig. 3