DESCRIPTION

Apparatus and method for measurement of the muzzle velocity of a projectile or the like

DE 697 09 291 T2 (EP 0 840 087 B1) discloses means for controlling the initial velocity of a projectile. A sensor means is therefore provided which can measure a parameter related to the muzzle velocity. This is done with the aid of the sensors which are fitted at least in or to the weapon barrel and can record a higher pressure in the weapon barrel which occurs as a result of the heating of the propellant gases adjacent to the weapon barrel. Strain gauges are proposed as sensors, and are adapted such that they make contact with the weapon barrel. In this case, the strain on the weapon barrel is measured. The movement and therefore the velocity of the projectile are determined from the time difference between the registration of the projectile passage by the two individual sensors.

DE 10 2005 024 179 A1 dispenses entirely with direct measurement of the current muzzle velocity, since the actual muzzle velocity is determined by information relating to the current speed of flight of the projectile, that is to say it is calculated back from this. This current muzzle velocity is then used to correct the preset initiation time for the initiation time of the projectile, with the aid of a standard muzzle velocity, and this is used as the current fuze setting time. A microwave transmitter, preferably in the GHz range, is used to transmit this information to the projectile, and transmits the current fuze setting, which is defined for example by a fire control, to the munition or a projectile.

A further method is to operate the barrel as a round waveguide and to measure the Doppler velocity of the projectile in the barrel, as disclosed in EP 0 023 365 A2. In this case, the frequency of the signal is higher than the cut-off frequency for the relevant waveguide mode. The electromagnetic wave which builds up in this case propagates in the barrel and is reflected by the projectile. Furthermore, this results in a Doppler frequency shift, which is dependent on the instantaneous velocity.

DE 27 17 949 A1 describes an appliance for measurement of velocities in the barrel using electromagnetic waves, wherein the waveguide wavelength of the barrel is used as a measure of the movement change of a projectile in the barrel. A transmitter and a receiving detector are for this purpose arranged at the same distance from the barrel. In this case, the projectile is used as a reflector for the electromagnetic waves. A rotationally symmetrical version of a horn emitter is fitted to the barrel muzzle. A mirror is arranged obliquely in the projectile direction and appropriately deflects the waves coming from the rectangular horn emitter into the barrel. The waveguide wavelength of the barrel is defined such that, in a special trial, a mirror for the electromagnetic waves is shifted slowly in a defined manner in the barrel, instead of the projectile, thus recording the distance between two maxima, by measurement.

EP 0 331 670 A1 discloses a method and a device for determining internal ballistic characteristic variables in tube weapons, wherein an electromagnetic wave is injected via a waveguide junction which is provided at the side on the weapon barrel, and is output again after reflection on the projectile in the weapon barrel, thus allowing significant measurements even with a live round. This is based on the fundamental

idea of emitting at least half of the energy of the electromagnetic waves out of the muzzle of the weapon barrel, instead of injecting this in the direction of the projectile. In order to inject the waves, these are split and are supplied to the weapon barrel at at least two points, which are separated from one another, on the waveguide junction, as a result of which the wave components which propagate in the direction of the projectile are added and compensate for the wave which propagates in the opposite direction.

The subsequently published DE 10 2006 058 375.2 proposes that the weapon barrel or the launch barrel and/or parts of the muzzle brake be used as a waveguide (a waveguide is a tube with a characteristic cross-sectional shape which has a very highly electrically conductive wall. In particular, rectangular and round waveguides are technically in widespread use), which, however, is operated below the cut-off frequency of the relevant waveguide mode. The distance between the transmitting coupler and receiving coupler is in this case fixed.

Following the same idea, the object of the invention is to specify a further measurement method, which allows the muzzle velocity of a projectile or the like to be determined excellently and accurately.

The object is achieved by the features of Patent Claim 1. Advantageous embodiments are specified in the dependent claims.

The invention is based on the idea of measuring or determining the muzzle velocity itself, preferably before or after the projectile, in which case a combination considerably increases the measurement accuracy. For measurement before the projectile, consideration is then given to the fact that the nose

of the projectile influences the electromagnetic field as it passes through the waveguide. This influence is compensated for by the fact that the munition type is in general known, as a result of which values which define the projectile are used, which make it possible to compensate for the influence of the nose on the measurement. In the case of measurement after the projectile, the cylindrical shape of the base is used, as a result of which the measurement is independent of the shape of the nose of the projectile. In this case, the base influences the electromagnetic field. The measurement method after the projectile has passed through can be used because most types of projectiles have flat cylindrical bases. This respective change is detected by a receiving coupler, and is supplied to an evaluation device.

A smooth barrel of any desired cross section is preferably used as a waveguide, in contrast to the situation in the subsequently published application (see above), in which a profiled waveguide is used as the waveguide. Furthermore, the electromagnetic field is detected without the presence of the projectile with the aid of at least one transmitting coupler and one receiver coupler, that is to say before the projectile passes through the waveguide. The last sample values before each projectile passes through are used to calibrate the measurement. The calibration therefore covers all temperature-dependent influences, and other influences. When the projectile passes through, the rate of change of the electromagnetic field is detected, and is normalized using the calibration. The muzzle velocity is therefore measured independently of temperature changes or other influences.

The signal generator (for example oscillator) produces a signal with a constant mid-frequency, which is operated below the lowest cut-off frequency of the

waveguide. As a result of the geometry and the nature of the transmitting coupler (coil, dipole etc.), a plurality of waveguide modes (TE_{mn} where m = 0, 1, 2 ... and n = 1, 2, 3 ...) are excited. The signal generator produces either a carrier in the continuous-wave mode (CW mode), or a modulated signal.

The distance between a transmitting coupler, which itself receives the signals from the oscillator, and the receiving coupler is variable, and can be selected individually depending on the mode selection of the waveguide, but is dependent on the calibre, the internal size of the waveguide, and the frequency.

The invention will be explained in more detail with reference to one exemplary embodiment and the drawing, in which:

Figure 1 shows a measurement arrangement for measurement of the muzzle velocity of a projectile before the projectile,

Figure 2 shows a measurement arrangement for measurement of the muzzle velocity of the projectile after the projectile.

1 denotes a smooth waveguide (barrel) in which (at least) one transmitting coupler 2 and (at least) one receiving coupler 3 are included. An oscillator 4 is connected to the transmitting coupler 2, and an evaluation device 5 is connected to the receiving coupler 3. The muzzle velocity of a projectile 6 can be determined using the abovementioned elements. 7 denotes the muzzle of the weapon or launch barrel 1.

The oscillator 4 excites a waveguide mode via the transmitting coupler 2 (transversal electrical mode = TE and transversal magnetic mode = TM. The desired

waveguide mode is excited by mechanical and electromagnetic mode selection.) In a first step, the electromagnetic field is measured without a projectile 6. The “barrel” system 1 (waveguide 1) results in a signal strength which the receiving coupler 3, for example a pick-up sensor, receives, and which is passed to the evaluation unit 5. The measurement is then carried out before the projectile 6 (Figure 1) and/or after the projectile 6 (Figure 2).

The distance between the transmitting coupler 2 and the receiving coupler 3 is variable, and can be selected individually depending on the mode selection of the waveguide 1, but is dependent on the calibre, the internal size of the waveguide 1, and the frequency.

When waveguide modes are excited by the transmitting coupler 2, then the received signal (for example induced voltage) at the receiving coupler 3 may have the following form:

$$U_{Ind} = \sum_{n=1}^{\infty} A_n \cdot e \frac{p_n}{a} \cdot z_k$$

where a is the internal radius of the waveguide 1 and A_n as well as p_n are dependent on n. In this case, $p_1<p_2<p_3<...$

z_k is itself chosen such that the received signal is dominated, for example, only by the term n=1 (single mode operation).

$$\Rightarrow U_{Ind} \approx A_1 \cdot e \frac{p_1}{a} \cdot z_k$$

This is possible because the terms for n = 2, 3, 4 for z_k are much smaller than the term n=1. This is important, in particular because the term with n=1

ensures a reliable velocity measurement of the projectile as it passes through.

The term $e^{\frac{p_1}{a} \cdot z_k}$ is primarily dependent on a, which itself is governed by the calibre. Since the frequency of the transmitted signal is lower than the cut-off frequency, this results in the received signal having an exponential profile.

If the measurement is carried out after the projectile 6 has passed through, the receiving coupler 3 must be placed between the projectile base and the transmitting coupler 2. If the measurement of the velocity V_0 is carried out before the projectile 6 passes through, the receiving coupler 3 should be located between the projectile nose and the transmitting coupler 2. If both measurement methods are combined, two receiving couplers 3 must be included in a corresponding manner. The transmitting coupler 2 would then need to be positioned between the two receiving couplers 3.

The signal processing should be carried out as follows:

As is known, as the projectile 6 flies past the receiving coupler 3, it produces a characteristic signal. The time profile of the received signal provides information about V_0.

In order now to obtain V_0 from the received signal, the signal is sampled continuously in time in the evaluation device 5, and the sample values are stored. This is done even when no projectile 6 is present. When a projectile 6 passes through the waveguide 1, the evaluation unit 5 is aware of the presence on the basis of the characteristic profile of the received signal. These values are evaluated in order to determine V_0.

Since the evaluation algorithm uses the internal radius a of the waveguide 1, temperature-dependent changes in the internal radius a may result in a measurement inaccuracy. In order, for example, to compensate for these influences, the empty waveguide is measured before each projectile passes through. This current value is used to scale the relevant sample values, and is stored and called up by the evaluation unit for the measurement evaluation (calibration).

PATENT CLAIMS

1. Apparatus for measurement of the muzzle velocity (V_0) of a projectile (6) or the like, comprising
   - a smooth weapon or launch barrel as a waveguide (1),
   - a signal generator (4) which
     - is electrically connected via a signal supply to at least one transmitting coupler (2) for excitation of the weapon or launch barrel (1), and
   - a receiving line for passing on the signals measured at at least one receiving coupler (3) to an evaluation device (5), wherein
   - the distance between the transmitting coupler (2) and the receiving coupler or couplers (3) is variable and can be selected individually depending on the mode selection of the waveguide (1), and
   - the receiving coupler (3) is placed between the projectile base and the transmitting coupler (2) when measurement is carried out after the projectile (6) has passed through,
   - the receiving coupler (3) is located between the projectile nose and the transmitting coupler (2) when the measurement of the velocity (V_0) is carried out before the projectile (6) has passed through, and
   - in a combination of both measurement methods, at least two receiving couplers (3) are correspondingly included, while the transmitting coupler (2) is then placed between the two receiving couplers (3).

2. Measurement apparatus according to Claim 1, characterized in that the signal generator (4) generates a carrier in the continuous-wave mode (CW mode).

3. Measurement apparatus according to Claim 1, characterized in that the signal generator (4) generates a modulated signal.

4. Method for measurement of the muzzle velocity (V_0) of a projectile (6) or the like, having the following steps:
   - measurement of the electromagnetic field of the empty weapon or launch barrel (1) without a projectile (6),
   - the measurement of the electromagnetic field before the projectile (6) or after the projectile (6), or in combination,
   - determination of the muzzle velocity (V_0) from the measured signals.

5. Method according to Claim 4, characterized in that the signals are sampled continuously in time, and the sample values are stored.

6. Method according to Claim 4 or 5, characterized in that temperature-dependent changes or other influences are recorded and considered in a calibration process, for which purpose the empty weapon barrel (1) is measured before each projectile passes through.

7. Method according to one of Claims 4 to 6, characterized in that values which are determined with knowledge of the projectile (6) munition type are used in order to compensate for the influence of the nose when measuring the electromagnetic field in front of the projectile (6).