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(54) **FULL-CALIBER, SPIN-STABILIZED GUIDED PROJECTILE WITH LONG RANGE**

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(57) **ABSTRACT**

An increased range guided projectile includes overcaliber lateral moment reducing wings (**10**) that can be deployed. The lateral moment reducing wings (**10**) are designed and arranged behind the center of gravity (S) in the tail direction on the guided projectile (**1**) so that the pitching moment derivative coefficient ($C_{m\alpha}$) of the guided projectile (**1**) is in the range of ±0.5, if the guided projectile (**1**) has a speed that is in the speed range of Mach 0.4 to 0.8; the lateral moment reducing wings (**10**) are in their deployed position; and, the canard guide device (**20**) does not exert any guiding moments.

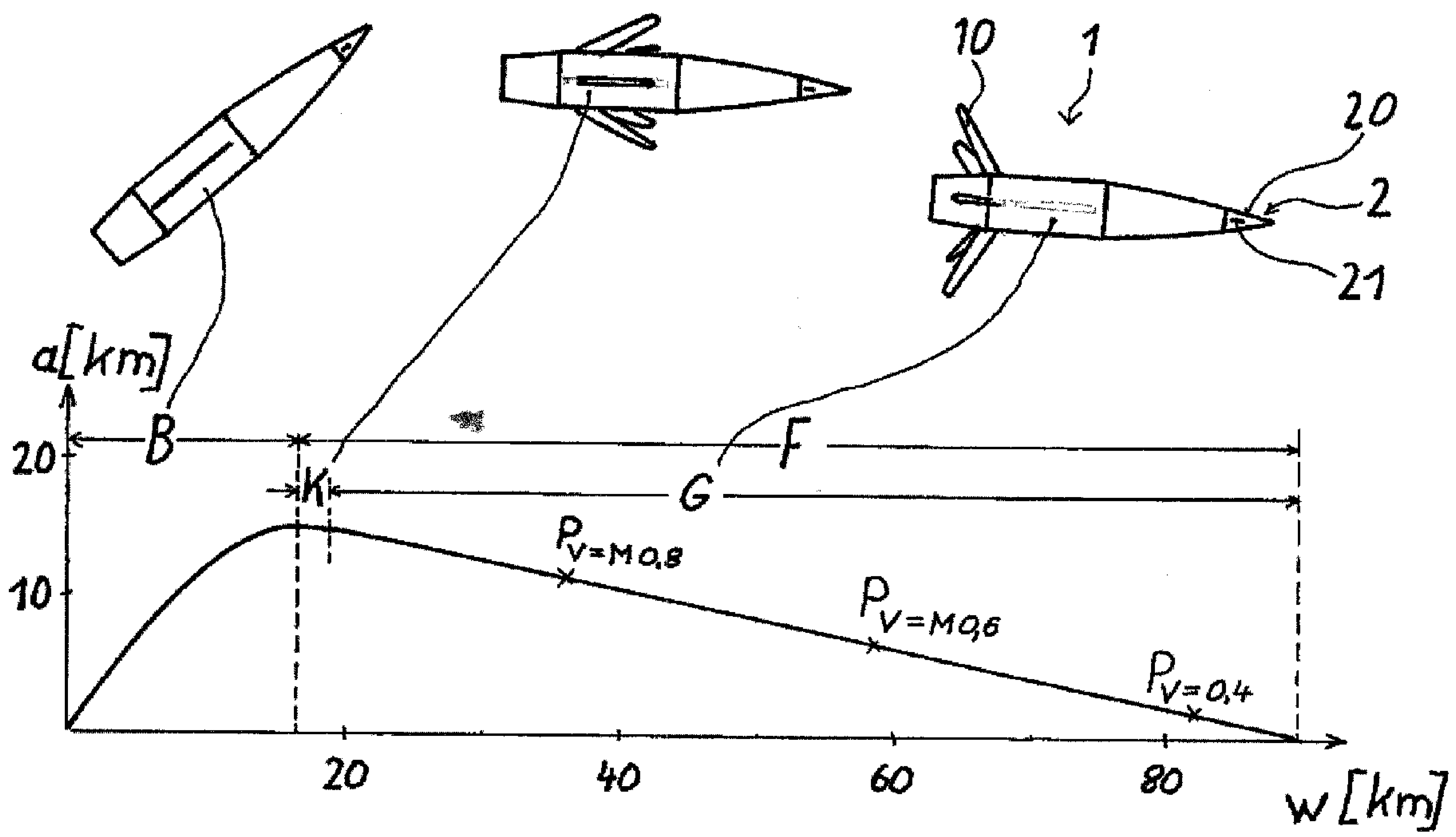


Fig. 1

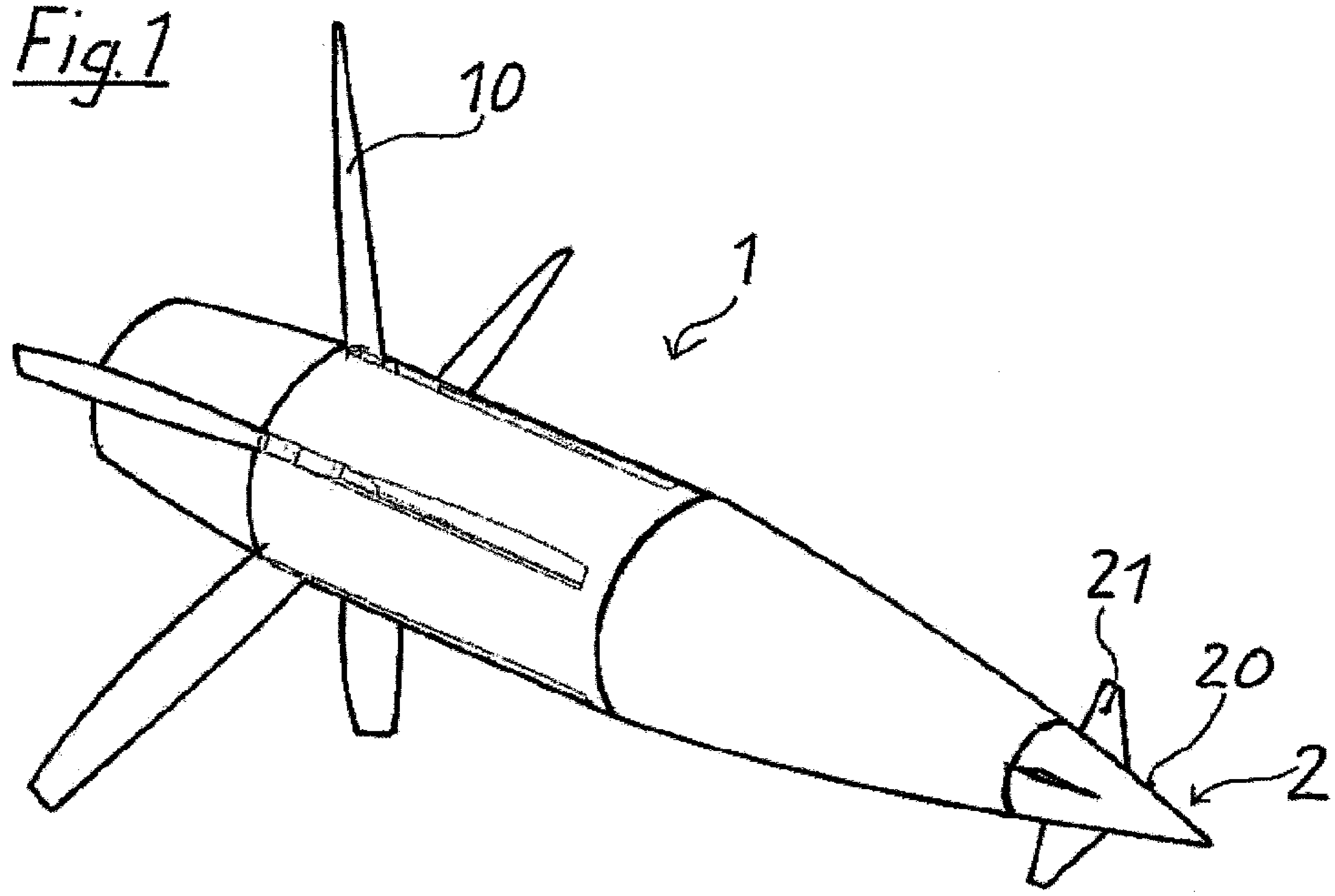


Fig. 2

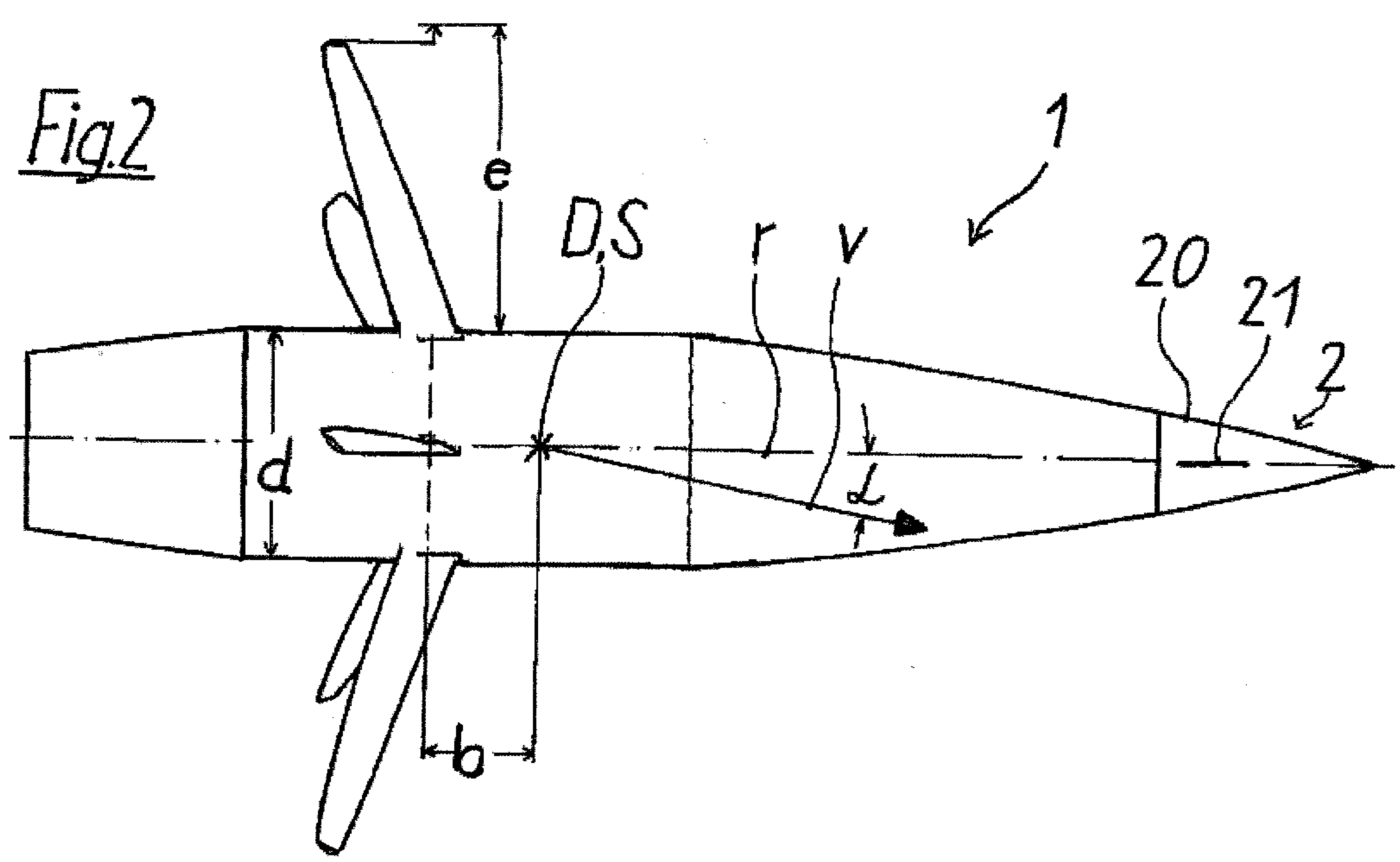
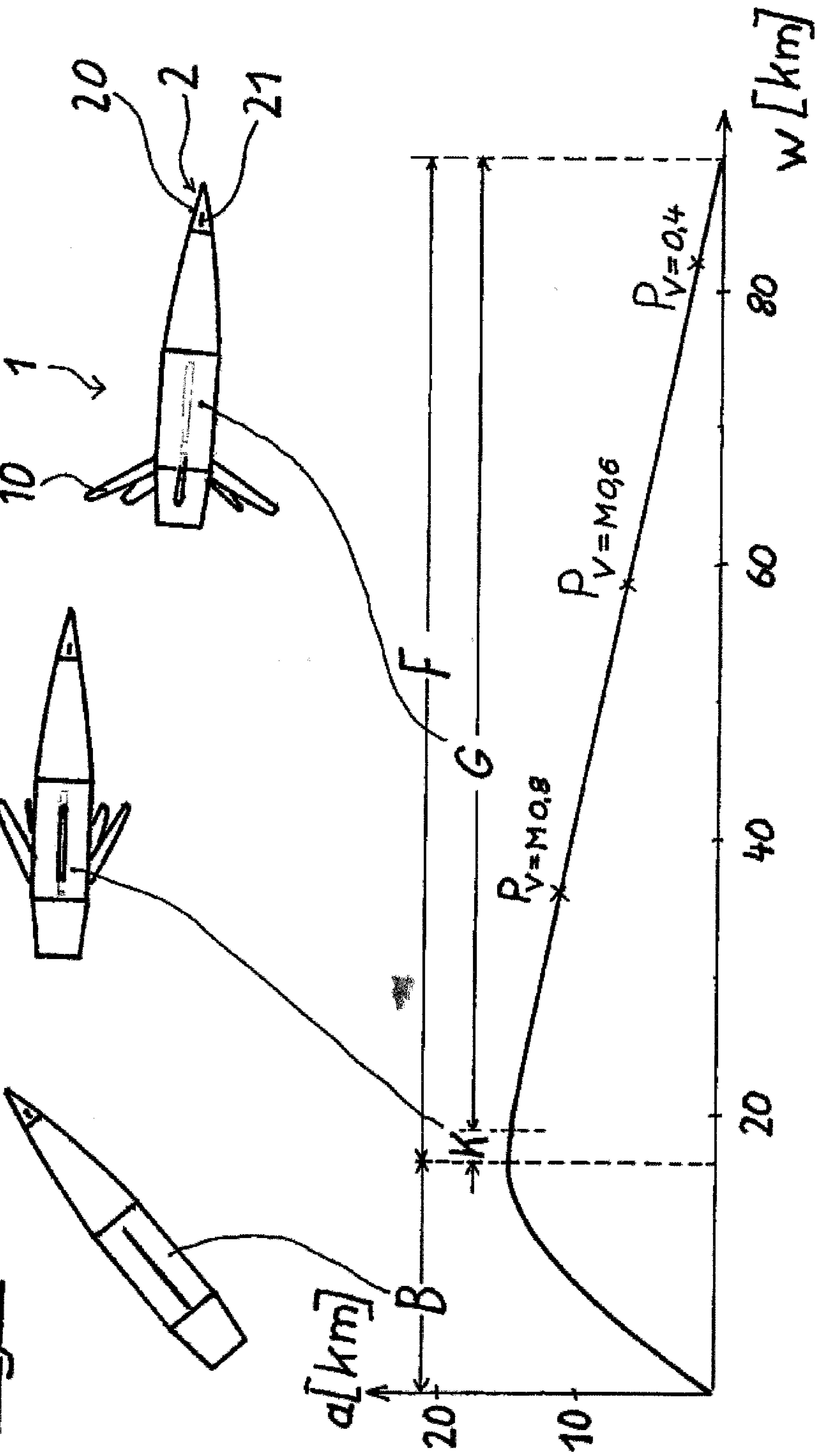


Fig.3



FULL-CALIBER, SPIN-STABILIZED GUIDED PROJECTILE WITH LONG RANGE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims foreign priority under 35 USC 119 to German application no. 102015013913.4 filed on Oct. 27, 2015.

[0002] FIELD OF INVENTION

[0003] The invention relates to a guided projectile that is spin-stabilized over the whole flight trajectory and that can be guided from the top of the trajectory to the target.

BACKGROUND

[0004] In a textbook on exterior ballistics (Title: Modern Exterior Ballistics, Author: Robert L. McCoy, ISBN: 0-7643-0720-7, year of publication: 1999), the fundamentals of spin stabilization and the distinction in comparison to fins stabilization are mentioned. In spin stabilization, the point of application of the normal force is located forward of the center of gravity of the projectile. We can find in this document the various aerodynamic coefficients which influence the flight trajectory, such as the pitching moment derivative coefficient $C_{m\alpha}$. A formula (page 37, numbered (2.25)) indicates that the caliber-related distance between the point of application of the normal force and the center of gravity of the projectile corresponds to the quotient of the pitching moment derivative coefficient $C_{m\alpha}$ and the normal force derivative coefficient $C_{N\alpha}$.

[0005] A guided projectile can be a conventional large-caliber, 155-mm full caliber missile with high useful load having a precision guidance kit that is screwed to the nose of the guided projectile (projectile with a Precision Guidance Kit (PGK), published and described on the Internet page: http://en.wikipedia.org/wiki/XM1156_Precision_Guidance_Kit). The guided projectile is designed so that it is spin-stabilized over the entire flight path. The spin stabilization results in a good stabilization of the projectile. In contrast to fins stabilization with tail wings, the drag is lower in the case of spin-stabilized projectiles. Accordingly, spin-stabilized projectiles have a long range. However, spin-stabilized projectiles are difficult to guide. The precision guidance kit on the nose of the projectile comprises a canard guide device with canard guide wings. Canard guide devices represent widely used guide devices and are part of a guide, navigation and control system. The canard guide wings are the only wings of the projectile with the precision guidance kit. Since the canard guide wings are fixed and a fixed guide moment is generated depending on the turning position in space, a guiding occurs via a control of the rotation angle or rotation rate of the roll-decoupled canard guide device by means of an electric engine. Aerodynamic coefficients, such as the pitching moment derivative coefficient $C_{m\alpha}$, influence the flight path. In the case of a conventional 155-mm full caliber projectile without precision guidance kit, depending on the precise projectile geometry and the flight conditions, the pitching moment derivative coefficient $C_{m\alpha}$ is on the order of magnitude of 3 to 5. Correspondingly, the distance between the point of application of the normal force and the center of gravity of the projectile is on the order of magnitude of 1 to 3 times the caliber, that is to say in the range of 15 to 45 cm. The guided projectile has a range of approximately 30-35 km.

[0006] Below, documents are mentioned that, like the present invention, relate to guided projectiles that are also spin-stabilized in the last flight phase of the projectile: U.S. Pat. No. 7,963,442 B2 shows a guided projectile, which is designed so that it is spin-stabilized over the whole flight trajectory. The guided projectile comprises a nose with a guide device. Instead of canard guide wings, the guide device comprises a rotary adjustable projectile nose with an asymmetry. The incidence at the asymmetric projectile nose generates a guide force. The guided projectile can be a large-caliber full caliber projectile.

[0007] U.S. Pat. No. 6,666,402 shows an additional guided projectile, which is designed so that it is spin-stabilized over the whole flight trajectory. The guided projectile comprises a nose with a canard guide device with canard guide wings. The guided projectile is a large-caliber full caliber projectile. To increase the range, a rocket motor in the tail is used.

[0008] Below, guided projectiles are described which, in deviation from the present invention, are not spin-stabilized over the whole flight trajectory but are instead primarily fins stabilized at least in the last flight phase of the projectile, that is to say the guiding phase:

[0009] US 2014/0326824 A1 shows a guided projectile. The guided projectile is fins stabilized by means of roll-decoupled tail fins. The guided projectile comprises a nose with a canard guide device with canard guide wings. The guided projectile is a large-caliber full caliber projectile.

[0010] EP 2 165 152 B1 shows another guided projectile. The projectile is spin stabilized up to the top of the trajectory. By means of a rocket engine, the rotation rate is then reduced, in order to subsequently deploy the tail wings for fins stabilization. The guided projectile comprises a nose with a canard guide device with canard guide wings. The guided projectile is a large-caliber full caliber projectile.

[0011] EP 1 309 831 B1 shows another guided projectile designed as large-caliber full caliber projectile. The guided projectile comprises, in addition to a canard guide device with canard guide wings, in addition to a rocket engine and in addition to tail wings for fins stabilization, also aircraft-like wings, in order to increase the range over a long glide phase.

[0012] Below, a document is mentioned, which relates to a special wing design:

[0013] DE 20 16 05 A shows a projectile with twisted tail wings that can be deployed. Due to the twisting of the tail wings, a spin is forced onto the projectile, in order to stabilize the projectile.

[0014] Below, the terms associated with the Magnus force are discussed:

[0015] In specialist circles, a distinction is made between two main types of Magnus effects, both based on the rotation of the projectile: First, the classic Magnus effect, which relates to the projectile body. Second, the Magnus effect that occurs at the wings of the projectile and that is referred to in specialist circles as pseudo-Magnus effect.

SUMMARY OF THE INVENTION

[0016] The invention aims to increase the range of a guided projectile.

[0017] In one embodiment, this aim is achieved according to the invention by the features of claim **1**.

[0018] The advantages of the invention are based on the idea of the invention that the guided projectile comprises overcaliber lateral moments reducing wings that can be deployed and that the lateral moments reducing wings are designed and arranged behind the center of gravity in tail direction on the guided projectile so that the lateral moments are close to zero during a section of the descending flight phase. The lateral moments are equal to zero, if the point of application of the aerodynamic forces coincides with the center of gravity of the projectile.

[0019] In other words, the advantages of the invention are based on the idea of the invention that the lateral moments reducing wings are designed and arranged behind the center of gravity in tail direction on the guided projectile so that, during a section of the descending flight phase, the point of application of the aerodynamic forces almost coincides with the center of gravity of the projectile. If the point of application of the aerodynamic forces coincides with the center of gravity of the projectile, the lateral moments are equal to zero.

[0020] For this purpose, the lateral moments reducing wings are designed and arranged behind the center of gravity in tail direction on the guided projectile so that the pitching moment derivative coefficient $C_{m\alpha}$, of the guided projectile is in the range of ±0.5. This range of −0.5 to +0.5 means that the lateral moments, more precisely the static lateral moments, which will be explained in further detail in the context of the embodiment examples, are close to zero. In other words, this means that the point of application of the aerodynamic forces, more precisely the static point of application of the aerodynamic forces, and the center of gravity almost coincide. The complete range of ±0.5 of the pitching moment derivative coefficient $C_{m\alpha}$ of the guided projectile is present if:

- **[0021]** a) first, the guided projectile has a speed which is in the speed range of Mach 0.4 to 0.8. Due to the dependency on the speed, the lateral moments reducing wings can be optimized only for a certain speed. Since the speed in the guided phase is predominantly in the speed range of Mach 0.4 to 0.8, one optimizes the lateral moments reducing wings to a speed in the mentioned speed range.
- **[0022]** b) second, the lateral moments reducing wings are in their deployed position, as is the case in the guiding phase.
- **[0023]** c) third, the canard guide device does not exert any guide moments. Indeed, guide moments of the canard guide device change the lateral moments and thus the pitching moment derivative coefficient $C_{m\alpha}$ of the guided projectile. Accordingly, the low pitching moment derivative coefficients $C_{m\alpha}$ are obtained if the canard guide device has a neutral behavior.

[0024] The lateral moments reducing wings produce a natural gliding of the projectile and a behavior that is almost like that of a perfect gyroscope, because there are almost no lateral moments. An optimal incidence angle, adjustable by means of the canard guide device, maximizes the range. Details on this are explained in the embodiment example.

[0025] Since the guided projectile glides in a natural manner and since the guided projectile behaves almost like a perfect gyroscope, only small setting forces of the canard guide device are needed. This means that small size canard wings, which increase the drag only slightly, are enough to guide the projectile in order to increase the range.

[0026] The lateral moments reducing wings form lift surfaces and thereby increase the range.

[0027] According to an advantageous design of the invention, the pitching moment derivative coefficient $C_{m\alpha}$ of the guided projectile is in the range of ±0.5 not only if

- **[0028]** the guided projectile has a speed, hereafter referred to as the nominal speed, which is in the speed range of Mach 0.4 to 0.8, but also
- **[0029]** in a complete speed range, which extends from the nominal speed minus a speed of Mach 0.1 to the nominal speed plus a speed of Mach 0.1. The greater the speed range for which low pitching moment derivative coefficients $C_{m\alpha}$ are implemented is, the greater the range of the guided projectile is.

[0030] According to an additional advantageous design of the invention, the lateral moments reducing wings in each case comprise an attachment end, and the axial distance between the lateral moments reducing wings, measured at the center of the attachment end, and the center of gravity S is 0.01 times to 1.0 times the caliber. Within the indicated axial distance range it is possible that the pitching moment derivative coefficient $C_{m\alpha}$ of the guided projectile can be reduced to small values.

[0031] According to another advantageous design of the invention, each lateral moments reducing wing in the deployed position protrudes with a radial extension over the cladding of the guided projectile, in such a manner that the radial extension is 0.8 to 2 times the caliber of the guided projectile. The extent of the radial extension of the lateral moments reducing wing over the cladding of the guided projectile is an important parameter. Long lateral moments reducing wings increase the lift, but also the air resistance. Furthermore, the local speed at the outer tip of the lateral moments reducing wings must not be close to Mach 1, because in that case the drag would be too high. The design is such that the local speed at the outer tip of the lateral moments reducing wings is less than Mach 1. This explains the indicated radial extension of 0.8 to 2 times the caliber. This will also be discussed more precisely in the context of the embodiment examples.

[0032] According to an additional advantageous design, the lateral moments reducing wings are twisted like a propeller, so that at least during a section of the descending flight phase, rotation energy is converted into translation energy, and so that at least in this process the lateral moments reducing wings are non-rotatably connected to the guided projectile. This results, on the one hand, in an increase in the range, since the translation speed is increased while the rotation speed is decreased. Furthermore, the pseudo Magnus force is reduced, since the wing profile follows the local speed vector.

[0033] According to an additional advantageous design, the lateral moments reducing wings are mounted in a roll-decoupled manner. The roll decoupling of the lateral moments reducing wings reduces the rotation rate of the lateral moments reducing wings and thus also the pseudo Magnus effects, which depend on the value of the rotation rate of the lateral moments reducing wings.

[0034] According to another advantageous design, the guided projectile exclusively comprises the canard guide wings and the lateral moments reducing wings. This simplifies the design and construction of the guided projectile.

[0035] According to another advantageous design, the canard guide device is designed so that the canard guide wings can be deployed and retracted. In the retracted position, the drag is low and the range is increased. The canard guide wings are retracted in the ballistic ascending phase and also in the guiding phase, if no correction of the flight path is needed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0036] Embodiment examples of the invention are described in further detail below in reference to the drawings. Here, in each case in the form of a schematic diagram:

[0037] FIG. **1** shows a guided projectile with lateral moments reducing wings, in a perspective representation;

[0038] FIG. **2** shows the guided projectile shown in FIG. **1** with explanatory entries, in the front view;

[0039] FIG. **3** shows a course of a flight trajectory of the guided projectile shown in FIGS. **1** and **2**.

DETAILED DESCRIPTION

Guided Projectile with Lateral Moments Reducing Wings

[0040] FIG. **1** shows a guided projectile **1**. The guided projectile **1** is designed so that it is spin-stabilized over the whole flight trajectory. The guided projectile **1** comprises a nose **2** with a canard guide device **20** with canard guide wings **21**. The guided projectile **1** is a large-caliber full caliber projectile of caliber 155 mm. In deviation from the embodiment example represented, the caliber could also have other values. The guided projectile **1** comprises deployed overcaliber lateral moments reducing wings **10**, the function of which will be described in detail below.

Canard Guide Device

[0041] The canard guide device **20** is roll-decoupled and can be driven via an axial engine. Furthermore, the canard guide device **20** is part of a guide, navigation and control system. The canard guide device **20** is designed so that the canard guide wings **21** can be deployed or retracted to a greater or lesser extent. In the retracted positions, the drag is reduced. In deployed positions of a canard guide wing **21**, guide forces are generated. The canard guide wings **21** are used in order to set the incidence angle α drawn in FIG. **2** in accordance with the guiding rules, so that the target is hit. The incidence angle α is the angle between the symmetry axis r of the guided projectile **1** and the speed vector v. Alternatively, canard wings can also be used for roll decoupling and for setting of the roll angle. Again, alternatively, other designs of canard guide devices can be used, of which many are known in the prior art.

Flight Phases

[0042] FIG. **3** illustrates the different phases of the flight path. A ballistic ascending phase B is followed by a descending flight phase F. The descending flight phase F consists of both a deployment phase K and a guiding phase G. FIG. **3** represents a coordinate system in which the altitude a is plotted over the range w.

[0043] Ballistic ascending phase B: During the acceleration in the weapon tube and during the ballistic flight up to the top of the trajectory the lateral moments reducing wings **10** are in a retracted position. The roll-decoupled guide device **20** is first interlocked to the rest of the guided projectile **1**, so that the roll-decoupled guide device **20** rotates with the same rotation rate as the rest of the guided projectile **1**. Alternatively, the guide device **20** can already be roll-decoupled in the ballistic ascending phase B. The guided projectile **1** is spin-stabilized with a high rotation rate during the entire ballistic ascending phase B, in which the lateral moments reducing wings **10** are retracted.

[0044] Deployment phase K: Near the top of the trajectory, the guide, navigation and control system is activated. The lateral moments reducing wings **10** are deployed. The rotation interlocking of the canard guide device **20** is released. The guide, navigation and control system calculates a target roll angle and ensures that the nose **2** of the guided projectile **1** follows the target roll angle by means of the axial engine. Other designs of a canard guide device without axial engine can also be used, wherein the wings of the canard guide device set the target roll angle.

[0045] Guiding phase G: After the deployment phase K, the lateral moments reducing wings **10** are completely deployed. During the guiding phase G, the lateral moments reducing wings **10** remain in the completely deployed position. The canard guide device **20** is active. While maintaining a calculated roll angle, the guide forces are generated in that the individual canard guide wings **21** can be deployed or retracted to a greater or lesser extent.

Technical Design of the Guided Projectile for Increasing the Range

[0046] Below, FIG. **2** is discussed in detail. The guided projectile **1** comprises overcaliber lateral moments reducing wings **10**, which are designed and arranged behind the center of gravity S in tail direction on the guided projectile **1** so that the pitching moment derivative coefficient $C_{m\alpha}$ of the guided projectile **1** is in the range of ±0.5, if:

- **[0047]** the guided projectile **1** has a speed which is in the speed range of Mach 0.4 to 0.8,
- **[0048]** the lateral moments reducing wings **10** are in their deployed position, and
- **[0049]** the canard guide device **20** does not exert any guide moments.

Increase of the Range of the Guided Projectile

[0050] In principle, if no yawing moment is exerted on a spin-stabilized guided projectile **1**, the symmetry axis r retains its angular position. In the ideal case, when all the pitching and yawing moments are equal to zero and no guiding of the guided projectile **1** occurs, the equilibrium position is theoretically reached. In the equilibrium position, the angular position of the symmetry axis r and the speed vector v in a natural way forms an incidence angle α, wherein the speed vector v follows the flight path curve in accordance with the force of gravity. The incidence angle α is a constant parameter and would increase in the guiding phase G, if the canard guide device would not exert correcting guide forces. Since both the lift and also the drag increase with increasing incidence angle α, an optimal incidence angle α exists, which maximizes the range. Approximately, the optimal incidence angle is the incidence angle that has the best lift to air resistance ratio.

[0051] In spite of the lateral moments reducing wings **10**, in practice, residual small pitching and yawing moments remain. However, the canard guide wings **21** do not need to generate large guide moments in order to set an optimal incidence angle α between the symmetry axis r and the speed vector v for long ranges to be achieved.

[0052] For a better understanding of the above statements, the decomposition of the aerodynamic moments is discussed in detail below. With respect to the symmetry axis r, the resulting aerodynamic moments can be decomposed into a roll, a pitching and a yawing component. The lateral pitching moment moreover can be decomposed in a sum of a static term, the so-called static pitching moment, a damping term, and a dynamic term, the so-called pseudo Magnus moment. Corresponding statements apply to the lateral yawing moment. The lateral moments reducing wings **10** are arranged and designed so that the static air attack point D (this is understood to mean the static air attack point is the static point of application of the aerodynamic forces of the guided projectile including the drag forces and the lift forces) coincides to the extent possible with center of gravity S of the guided projectile **1**, when the canard guide wings **21** are retracted. As a result, the static pitching and yawing moments decrease close to zero. As pitching and yawing moments, only the damping and pseudo Magnus terms remain. The damping terms of the pitching and yawing moments contribute to the stability of the symmetry axis r of the guided projectile **1**. The pseudo Magnus terms are reduced, in that either propeller-like twisted, non roll-decoupled or roll-decoupled lateral moments reducing wings are used, which will be discussed in greater detail below. Since all the aerodynamic forces depend on the Mach number, the static pitching and yawing moments are close to zero during a section of the descending flight phase F.

[0053] When the static pitching and yawing moments are close to zero due to the lateral moments reducing wings **10**, and when the pseudo Magnus moments are reduced, then all the lateral aerodynamic moments are very small and very reduced in comparison to a conventional 155-mm projectile. In this case, the guided projectile **1** will behave almost like a perfect gyroscope, and the symmetry axis r of the guided projectile **1** remains nearly in the same direction. In the descending flight phase F, one has a situation with a symmetry axis r of the guided projectile **1** that remains nearly constant and with a curved flight path corresponding to the force of gravity. In a natural manner, an incidence angle α forms, which leads to the guided projectile **1** gliding, in that upward directed, vertical lift forces are produced on the guided projectile which compensate the gravity, so that the range is increased. The smaller the angle of inclination of the flight path is, the greater the range is.

[0054] This confirms the theory of classic aeroballistics. In classical aeroballistics, the incidence angle α is formed using the sum of 3 three terms: First, the yaw of repose term, second, the precession term, and third, the nutation term. From the mathematical viewpoint, the yaw of repose angle is a complex parameter comprising the vertical incidence angle and the lateral sideslip angle. In the case of a conventional ballistic 155-mm projectile without canard wings, the yaw of repose angel in the vicinity of the top of the trajectory is a lateral sideslip angle, which leads to a lateral lift force and thus to a lateral deflection of a conventional ballistic 155-mm projectile. Since the static lateral moments are brought to values that are close to zero, the lateral sideslip angle is theoretically converted into a vertical incidence flow angle, which increases the range.

Determination of the Precise Arrangement of the Lateral Moments Reducing Wings **10**

[0055] In reality, the aerodynamic moments depend on the flight conditions. It would be possible to keep the static aerodynamic lateral moments close to zero over a long time period, by changing the geometry of the lateral moments reducing wings **10** or their sweep angle during the descending flight phase F. However, this would require additional engines, which increase the cost of the guided projectile **1** too much and make it too complicated. However, it is possible to bring the static lateral aerodynamic moments close to zero during a section of the flight path of the guiding phase G.

[0056] In order to reduce the static lateral aerodynamic moments to close to zero, the lateral moments reducing wings **10** are arranged, depending on their wing size and geometry, at carefully determined positions on the guided projectile **1**. In order to minimize the pitching and yawing moment, the lateral moments reducing wings **10** are arranged slightly in the area of the center of gravity area of the tail, in order to compensate for the moment of the normal force of the body, the point of application of the normal force of the body is located in the front area of the center of gravity. As explained above, the position of the lateral moments reducing wings **10** is optimized for the guiding phase G, which is a subsonic flight phase. The design of the lateral moments reducing wings **10** and the determination of the precise arrangement of the lateral moments reducing wings **10** occur in several steps:

[0057] A first design and arrangement of lateral moments reducing wings **10** is selected so that the pitching moment derivative coefficient $C_{m\alpha}$, of the guided projectile **1** for a selected point of the flight path of the guiding phase is equal to zero. The selected point is located in a speed range of Mach 0.4 to 0.8, which is typical for guided projectiles. The selected speed, or in other words, the nominal speed is Mach 0.6 in the present example. Alternatively, another nominal speed in the speed range from Mach 0.4 to 0.8 could also be selected. In FIG. **3**, the points $P_{v=M0.8}$, $P_{v=M0.6}$ and $P_{v=M0.4}$ are drawn, for illustration.

[0058] Since the aerodynamic coefficients depend on the Mach, the first design and arrangement of lateral moments reducing wings **10** are optimized in such a manner that the pitching moment derivative coefficient $C_{m\alpha}$ of the guided projectile **1** is in the range of ±0.5 not only if

[0059] the guided projectile **1** has a nominal speed that is in the speed range of Mach 0.4 to 0.8, but also

[0060] in a complete speed range, which extends from the nominal speed minus a speed of Mach 0.1 to the nominal speed plus a speed of Mach 0.1. In reference to the present example, this means that the low pitching moment derivative coefficients $C_{m\alpha}$ of the guided projectile apply in the complete speed range of Mach 0.5 to Mach 0.7.

[0061] In a last step, the design and arrangement of the lateral moments reducing wings **10** can moreover be optimized further so that the lowest possible pitching moment derivative coefficients $C_{m\alpha}$ of the guided projectile are achieved for the entire guiding phase G.

[0062] The tools for the design and arrangement of the lateral moments reducing wings **10**:

[0063] The use of aerodynamic prediction computer programs (semi-empirical aerodynamics prediction codes, aerodynamic coefficient estimation tools),

[0064] Simulations (computational fluid dynamics (CFD) simulations),

[0065] Wind tunnel measurements,

[0066] Free flight tests.

[0067] If the pitching moment derivative coefficient $C_{m\alpha}$ is in the range of −0.5 to 0.5, then the distance between the static air attack point D and the center of gravity S is very small. This distance is about 0.05 times the caliber if the normal force derivative coefficient is on the order of magnitude of 10. With respect to the embodiment example of a 155-mm guided projectile, the distance is less than 8 mm.

[0068] This is apparent from the following formula:

$$x = \frac{C_{m\alpha}}{C_{N\alpha}} d = \frac{0.5}{10} d = 0.05d$$

[0069] where:

[0070] x is the distance between the static air attack point D and the center of gravity S;

[0071] d is the caliber;

[0072] $C_{m\alpha}$ is the pitching moment derivative coefficient, which should be at most ±0.5, wherein, in the formula, the upper positive limit value in the amount of 0.5 was used;

[0073] $C_{N\alpha}$ is the normal force derivative coefficient, which is on the order of magnitude of **10**.

[0074] Propeller-Like Twisted and Rotationally-Fixed Arrangement of the Lateral Moments Reducing Wings for the Speed Increase and Reduction of the Pseudo Magnus Effects

[0075] As shown in FIG. **1**, the lateral moments reducing wings **10** are twisted like a propeller. At least during a section of the descending flight phase F, rotation energy is converted into translation energy, if, as explained also below, the rotation speed is higher than the compensation rotation speed. At least the lateral moments reducing wings **10** are here rotatably attached to the guided projectile **1**. Depending on the size of the local incidence angle, the pseudo Magnus effects generate forces and moments on the lateral moments reducing wings **10**. The local incidence angle is reduced by the propeller-like twisting of the lateral moments reducing wings **10**, since the wing profile here follows the local speed vector.

Calculation of the Propeller-Like Twisted of the Lateral Moments Reducing Wings

[0076] The lateral moments reducing wings are twisted so that, at a distance r_i from the symmetry axis of the guided projectile, each cross section of a lateral moments reducing wing forms an angle α; with respect to the axis according to the following equation: tan $a_i = r_i W/V$, where W is the rotation speed (in rad/s) and V is the guided projectile speed. Example for a 155-mm missile at V=270 m/s and W=628 rad/s (100 Hz):

[0077] The angle is 10.15° at the lower portion of the lift wing (r_i=0.0775 m).

[0078] The angle is 35.6° at a distance of twice the caliber d from the symmetry axis r (r_i=2d).

[0079] This means that, at each distance r_i from the symmetry axis r of the guided projectile, the cross section of the lateral moments reducing wing **10** is co-linear with respect to the local speed vector, which results from the guided projectile speed and the peripheral speed due to the spin rate. Besides minimizing the pseudo Magnus moment, this improves the ratio of lift to drag. When the rotation speed is reduced, this results in the exertion of a traction force. If, during the transitional phase, after the deployment of the lateral moments reducing wings **10**, the rotation speed is higher than the compensation rotation speed, the guided projectile **1** is pulled until the compensation rotation speed is reached. The traction force on the lateral moments reducing wings **10** reduces the air resistance at the guided projectile **1** and improves the lift to drag ratio, as a result of which the range is increased.

Alternative to the Propeller-Like Twisting and the Rotationally Fixed Arrangement of the Lateral Moments Reducing Wings: Roll Decoupling

[0080] In deviation from the represented embodiment example, the lateral moments reducing wings **10** can also be mounted in a roll-decoupled manner. Here, the lateral moments reducing wings **10** can have a straight design, that is to say as design without twisting, or they can be designed with propeller-like twisting. A propeller-like twisted embodiment is selected if the lateral moments reducing wings **10** should rotate in a roll-decoupled manner with a low compensation rotation speed, which is predetermined by the propeller-like twisting. Due to the roll decoupling, the rotation rate and thus the pseudo Magnus effect are strongly reduced.

Radial Extension of the Lateral Moments Reducing Wings 10

[0081] As FIG. **2** illustrates, each lateral moments reducing wing **10** protrudes in the deployed position with a radial extension e over the cladding of the guided projectile **1**, so that the radial extension e is in the range of 0.8 to 2 times the caliber d of the guided projectile **1**. This is a compromise. Indeed, long lateral moments reducing wings **10** increase the lift, but also the drag. Furthermore, the speed at the outer tip of the lateral moments reducing wings **10** must not be greater than Mach 1, because otherwise the air resistance would be too high.

[0082] For the case in which the lateral moments reducing wings are twisted like a propeller and the lateral moments reducing wings are rotatably connected to the guided projectile **1**, the local speed at the outer tip of the lateral moments reducing wings **10** has the vector components of guided projectile speed and peripheral speed in accordance with the rotation rate. In order to achieve values of less than Mach 1 at the outer tips of the lateral moments reducing wings **10**, the rotation rate, which is 200 to 250 rotations per second (Hz) at the beginning of the descending flight phase, has to be reduced. Depending on the missile speed, the target rotation rate should be on the order of magnitude of 50 to 100 Hz. This is achieved by varying degrees of propeller-like twisting of the lateral moments reducing wings, which leads to the desired compensation rotation speed. As a result of the reduced rotation rate, the gyroscope stability of the guided projectile is reduced. Therefore, the rotation rate should be optimized taking into consideration the aerodynamic features and the performance capacity of the guide, navigation and control system for the stabilization of the guided projectile.

[0083] In the case of rotation-decoupled lateral moments reducing wings, the rotation rate of these wings should be reduced, independently of the rotation axis of the rest of the guided projectile, so that it is not necessary to reduce the rotation rate of the guided projectile.

Distance of the Lateral Moments Reducing Wings 10 Behind the Center of Gravity S

[0084] In order to obtain a pitching moment derivative coefficient $C_{m\alpha}$ in the range of −0.5 to 0.5, the axial distance b between the lateral moments reducing wings **10**, measured at the center of the attachment end, and the center of gravity S, is 0.01 times to 1.0 times the caliber d. The axial distance b is measured at the level of the guided missile cladding surface.

[0085] The distance b will be small if, for example, the radial extension of the lateral moments reducing wings **10** is large. The distance b will be large if, for example, the radial extension of the lateral moments reducing wings **10** is small.

[0086] In FIG. **1** and in FIG. **3**, the axial distance between lateral moments reducing wings **10**, measured at the center of the attachment end, and the center of gravity S, is drawn too large in size and therefore not true to scale.

Tilt of the Lateral Moments Reducing Wings

[0087] The lateral moments reducing wings **10** are in a tilt arrangement in the deployed position, wherein the tilt is in flight direction. Alternatively, the tilt can also point to the forward. Alternatively, the lateral moments reducing wings **10** in the deployed position can also be arranged at a right angle with respect to the symmetry axis r of the guided projectile **1**.

Details on the Guided Projectile

[0088] As FIG. **1** shows, the guided projectile **1** comprises no tail guide mechanism, since the guided projectile **1** is spin-stabilized. Furthermore, the guided projectile **1** does not comprise a rocket engine, since the range is increased anyway by means of the lateral moments reducing wings **10**, and a rocket engine would increase the complexity and the costs of the guided projectile.

LIST OF REFERENCE NUMERALS

[0089] **1** Guided projectile
[0090] **2** Nose
[0091] **10** Lateral moments reducing wing
[0092] **20** Canard guide device
[0093] **21** Canard guide wing
[0094] D Static point of application of aerodynamic forces
[0095] S Center of gravity
[0096] r Symmetry axis
[0097] v Speed vector
[0098] α Incidence angle
[0099] d Caliber
[0100] b Axial distance between the center of gravity and the center of the attached end of a lateral moments reducing wing
[0101] e Radial extension of a lateral moments reducing wing
[0102] B Ballistic ascending phase
[0103] F Falling flight phase
[0104] K Deployment phase
[0105] G Guiding phase
[0106] a Altitude
[0107] w Range
[0108] Pv=M0.4 Point of the flight trajectory at which the speed is M 0.4
[0109] Pv=M0.6 Point of the flight trajectory at which the speed is M 0.6
[0110] Pv=M0.8 Point of the flight trajectory at which the speed is M 0.8

1. A guided projectile comprising the following features:
a) the guided projectile is designed so that it is spin-stabilized over the whole flight trajectory,
b) the guided projectile comprises a nose with a canard guide device with canard guiding wings,
c) the guided projectile is a large-caliber full caliber projectile,
d) the flight path of the guided projectile is influenced by aerodynamic coefficients, such as by a pitching moment derivative coefficient ($C_{m\alpha}$),
wherein:
e) the guided projectile comprises overcaliber lateral moments reducing wings that can be deployed,
f) the lateral moments reducing wings are designed and arranged behind the center of gravity in the tail direction on the guided projectile so that the pitching moment derivative coefficient ($C_{m\alpha}$) of the guided projectile is in the range of ±0.5, if
the guided projectile has a speed that is in the speed range of Mach 0.4 to 0.8,
the lateral moments reducing wings are in their deployed position, and
the canard guide device does not exert any guiding moments.

2. The guided projectile according to claim **1**, wherein the pitching moment derivative coefficient ($C_{m\alpha}$) of the guided projectile is in the range of ±0.5 not only if
the guided projectile has a speed, hereafter referred to as the nominal speed, that is in the speed range of Mach 0.4 to 0.8, but also
in a complete speed range extending from the nominal speed minus a speed of Mach 0.1 to the nominal speed plus a speed of Mach 0.1.

3. The guided projectile according to claim **1**, wherein the lateral moments reducing wings in each case comprise an attachment end, and the axial distance between the lateral moments reducing wings, measured at the center of the attachment end, and the center of gravity is 0.01 times to 1.0 times the caliber.

4. The guided projectile according to claim **1**, wherein
in the deployed position, each lateral moment reducing wing protrudes with a radial extension over the cladding of the guided projectile, so that the radial extension is 0.8 to 2 times the caliber of the guided projectile.

5. The guided projectile according to claim **1**, wherein
the lateral moment reducing wings are twisted like a propeller, and during a section in a descending flight phase, rotation energy is converted into translation energy, wherein at least in this process the lateral moments reducing wings are non-rotatably attached to the guided projectile.

6. The guided projectile according to claim **1**, wherein
the lateral moments reducing wings are mounted in a roll-decoupled manner.

7. The guided projectile according to claim **1**, wherein
the guided projectile comprises no additional wings besides the canard guiding wings and the lateral moments reducing wings.

8. The guided projectile according to claim **1**, wherein the canard guide device is designed so that the canard guide wings can be deployed and retracted.

9. The guided projectile according to claim **1**, wherein the lateral moment reducing wings are twisted so that, at a distance r_i from the symmetry axis of the guided projectile, each cross section of a lateral moment reducing wing forms an angle a_i with respect to the axis according to the following equation: $\tan a_i = r_i W/V$, where W is the rotation speed (in rad/s) and V is the guided projectile speed.

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