Missile nose and method for steering a missile

The invention is based on a missile nose and a method for steering a missile.

A missile which flies under the surface of the water, for example, a rocket or a high-speed torpedo, is subject to high drag. At high speeds of flight, this drag can be reduced considerably by the missile nose having a cavitator which forms a cavitation bubble in which the rest of the missile can fly essentially without touching the surrounding water.

Conventional steering systems for missiles without a cavitator often have a number of mutually independent control surfaces which are arranged on the missile hull and are moved accordingly in order to align the missile with a target. In the case of missiles with a cavitator, an arrangement of control surfaces such as this is inefficient since the direction of the missile cannot be influenced adequately by varying the position of the control surfaces within the cavitation bubble.

The object of the present invention is to specify a missile nose and a method for steering a missile which allow precise guidance of a missile to a target, in particular under water.

The object with regard to the missile nose is achieved by a missile nose with a nose tip which, according to the invention is mounted such that it can move relative to a supporting segment for supporting the nose tip for steering along a trajectory, with the missile nose also having an actuation means for movement of the nose tip. The missile is in this case controlled by pivoting movements of the cavitator, which is the only part of the missile which is in direct and continuous contact with the surrounding water.

The actuation means is advantageously arranged within the supporting segment. A target-seeking sensor can operate particularly effectively if as few disturbing parts as possible, in particular moving elements, are arranged between it and the target. The sensor is thus expediently

arranged in the missile nose. Since a sonar antenna, in particular occupies a relatively large amount of space, an antenna such as this is arranged as far as possible to the rear in a missile nose, that is to say well away from the narrow tip of the missile nose, which should thus be free of moving elements for controlling the movement of the nose tip. If the actuation means for movement of the nose tip is arranged within the supporting segment, the space within the nose tip can at least largely be made completely available for a target-seeking sensor. This allows the missile to be guided to a target particularly precisely.

A missile is regarded as being any appliance which is intended to produce a propelled, floating movement in an at least essentially homogeneous fluid, for example water or air, in particular a rocket or a high-speed torpedo. The nose tip may be in the form of a cavitator, which is intended to produce a cavitation bubble. The supporting segment may be provided for moving or fixed connection to a missile hull. The supporting segment supports the nose tip relative to, for example a motor in the missile, and may completely surround the entire part of the missile nose or of the missile that is arranged to the rear of the nose tip, to form a warnose segment or a propulsion segment. The actuation means expediently also has at least two elements which can be moved with respect to one another by means of a motor drive and whose relative movement with respect to one another is linked to movement of the nose tip relative to the supporting segment. In particular, the actuation means also has a motor drive. The actuation means advantageously comprises all of the moving parts for movement of the nose tip in at least one dimension.

The nose tip can advantageously be pivoted relative to the supporting segment about at least one axis which runs through the nose tip. This allows the axis to be arranged through the hydrodynamic centre of pressure of the nose tip – or more generally: the fluid-dynamic centre of pressure – thus allowing fluid-dynamic forces acting on the actuation means to be kept low.

With the same advantage, the missile nose has an attachment means for attachment to a missile hull, in which the case the nose tip can be pivoted relative to the attachment means about at least two axes which intersect at an intersection point within the nose tip. The two axes are, for example, a

pitch axis and a yaw axis which, in particular, are arranged at right angles to the axial direction of the missile nose, and whose interaction allows two-dimensional control of the missile nose and of the missile. It is also possible for the two axes to comprise a yaw axis in the axial direction of the missile nose, and the yaw axis or the pitch axis.

The intersection point is expediently located at the fluid-dynamic centre of pressure of the nose tip, thus making it possible to avoid larger forces acting on the actuation means. In this case, the intersection point is also still regarded as being arranged at the fluid-dynamic centre of pressure when the intersection point is arranged in a region up to 5% of the nose tip length away from a calculated fluid-dynamic centre of pressure.

Simple and precise movement of the nose tip about the intersection point can be achieved by the actuation means having a first element pair with a first and a second element, with the second element being mounted such that it can move together with the nose tip relative to the first element, and one of the elements having a first guidance means for guiding along the other element, and the guidance means being arranged concentrically with respect to the intersection point. A long distance between the element which can move relative to the nose tip and the intersection point allows the nose tip to be moved with relatively little force being applied. The concentric guidance allows simple but nevertheless stable and precise movement of the nose tip about the intersection point. The guidance means may be a sliding surface or a toothed rim, or any other suitable means. The concentricity is also ensured by the other element moving along the guidance means concentrically about the intersection point. In this case, the guidance means may, per se, comprise small elements which are not concentric, such as a tooth system, without departing from a concentric arrangement of the guidance means about the intersection point. The guidance element may be cylindrical or conical with a cylinder axis or cone axis which runs through the intersection point.

It also advantageous for the actuation means to have a second element pair which is arranged separately from the first element pair, with a third element and a fourth element, with the fourth element being mounted such that it can move together with the nose tip relative to the third element, and one of the elements having a second guidance means for guiding along the

other element, and the guidance means being arranged concentrically with respect to the intersection point. The nose tip can be moved in a simple and precise manner about two axes relative to the supporting segment or to the attachment means. The two guidance means can also expediently move relative to one another.

In a further advantageous refinement of the invention, the missile nose has a cavity which is formed by the nose tip with a rear outer wall and a guidance means, which is attached to the outer wall, for movement of the nose tip, with the intersection point being arranged in the cavity. The arrangement of the guidance means outside the cavity allows the cavity to be used at least largely for arrangement of a target-seeking sensor.

The cavity is expediently free of elements which move with respect to the outer wall, at least in front of the intersection point or in front of the fluid-dynamic centre of pressure. An active sensor beam can in this way be protected against being corrupted by moving elements. The direction statements "in front of" and "behind" relate to the direction of flight, with the missile nose tip being arranged in front, and the missile hull being arranged behind. It is also proposed that the nose tip have an outer surface which is provided for steering, and that the nose tip be free of moving elements within this outer surface. In the case of a conical outer surface, the cone volume is in this case free of moving elements.

In a further refinement of the invention, the missile nose has a supporting means, which is arranged concentrically with respect to the intersection point, for absorbing fluid-dynamic loads of the nose tip. The concentric arrangement allows a fluid-dynamic load to be transmitted uniformly to the supporting means independently of the movement position of the nose tip. The supporting means is in this case advantageously used to absorb essentially all of the fluid-dynamic loads on the nose tip.

The invention also proposes that the nose tip be mounted via a supporting means in the supporting segment, which is intended to transmit fluid-dynamic loads from the nose tip to the supporting segment with moving elements for movement of the nose tip being kept free of fluid-dynamic loads on the nose tip. The nose tip can be moved precisely to a desired

position, independently of the loads acting on it. The elements are expediently arranged within the supporting segment.

In a further embodiment of the invention, the missile nose has a ball cup for supporting the nose tip. The nose tip can be moved within the ball cup, in particular about the fluid-dynamic centre of pressure, with uniform force transmission to the supporting segment being maintained. The ball cup is expediently arranged concentrically with respect to the fluid-dynamic centre of pressure and, in particular, is firmly connected to an outer surface of the nose tip. The ball cup may have convex or concave curvature as a surface of a spherical section. In this case, the nose tip expediently has a convex ball cup, and the supporting segment has a concave ball cup, into which the ball cup on the nose tip can be inserted.

An advantageous geometry for the nose tip can be achieved by the nose tip having a conical outer surface. The fluid-dynamic centre of pressure of the nose tip may be located within a point in the nose tip independently of the movement position of the nose tip.

Agile manoeuvrability of a missile associated with alignment which is at least largely free of any rotational movement, for example of a sonar antenna with respect to a flying target, can be achieved by the nose tip being mounted such that it can pivot about three axes which intersect at an intersection point. The three axes are expediently aligned at right angles to one another.

Particularly reliable guidance to a target can be achieved by a sensor, which is arranged within the nose tip for flying target detection. The sensor may be an acoustic sensor, for example a sonar sensor. The nose tip can be held easily and in a stable manner on the supporting segment by a sprung bearing, which pulls the nose tip towards the supporting segment, for the nose tip. The sprung mounting may be achieved, for example by one or more spring elements in at least one actuation element.

The object with regard to the method is achieved by a method for steering a missile which, according to the invention has a moving nose tip and a sensor for flying target detection, in which the nose tip is moved in order to steer the missile, and the sensor completes the steering movement of the

nose tip. A sensor may be arranged in the area of the nose tip and thus in front of disturbing moving elements of the missile nose, with the movement of the sensor being taken into account by movement of the nose tip during flying target detection.

Further advantages will become evident from the following description of the drawing in which exemplary embodiments of the invention are illustrated. The drawing, the description and the claims contain numerous features in combination. Those skilled in the art will also expediently consider the features individually and combine them to form sensible further combinations.

In the figures:

Figure 1 shows a supercavitating missile flying under the surface of the water,

Figure 2 shows a missile nose of the missile shown in Figure 1, with a nose tip illustrated partially sectioned and schematically,

Figure 3 shows a further missile nose, illustrated partially sectioned, and

Figure 4 shows a diagram of a method for steering a missile.

Figure 1 shows a missile 4 which is flying at very high speed under the surface 2 of the water, with a missile nose 6 at whose front end a conical nose tip 8 is arranged. A missile hull 10 is arranged behind the missile nose 6, and has a motor 12 at its rear end. The missile 4 flies in a speed range of 100-200 m/s through the water, with the nose tip 8 creating a cavitation bubble 14 behind it, which surrounds the rest of the missile nose 6 and the missile hull 10. The missile hull 10 thus has no contact – during ideal flight – with the water. During real flight, however, the missile hull 10 is subject to sudden movements within the cavitation bubble 14, so that it touches the water repeatedly and is knocked back by it into the cavitation bubble 14. Such movement is detected by sensors, for example acceleration sensors, and is taken into account in the calculation of the course of the missile 4.

Figure 2 shows the missile nose 6 of the missile 4, illustrated partially sectioned and schematically. At its front end, the missile nose 6 has a nose tip 8, which has a conical outer surface 16 for steering the missile 4. The

outer surface 16 surrounds a cavity 18, which is formed by the outer surface 16 and a rear outer wall 20. Within this cavity 18, a sensor 22 is arranged which is in the form of a sonar antenna and receives sounds from outside the nose tip 8 through the outer surface 16. A bushing 24 is introduced into the rear outer wall 20, for cables for supplying electrical power to the sensor 22 and for transmitting signals between the sensor 22 and a control unit 26, which is illustrated only highly schematically in Figure 2. A guidance means 28 is attached to the bushing 24 and is rigidly connected to the outer surface 16.

On its rear outer surface, the outer wall 20 forms a convex ball cup 30, whose centre point is located at an intersection point 32 of three axes 34, 36, 38, about which the nose tip 8 can move relative to the missile hull 10. The three axes 34, 36, 38 are formed by a roll axis 34, a pitch axis 36 and a yaw axis 38. The roll axis 34 is parallel to an axial direction of the missile nose 6, and of the undeflected nose tip 8. The pitch axis 36 and the yaw axis 38, about which the nose tip 8 can be pivoted relative to a supporting segment 40 of the missile nose 6, are at right angles to one another and are each at right angles to the roll axis 34. The ball cup 30 or the rear outer surface of the outer wall 20 is mounted in a concave ball cup 42 in the supporting segment 40, which has the same radius and sphere centre point as the ball cup 30. The ball cup 42 is part of the supporting segment 40, which supports the nose tip 8 during flight. The two ball cups 30, 42 allow the nose tip 8 to be moved freely in two dimensions about the intersection point 32. The two ball cups 30, 42 are provided with a coating, which prevents destruction of the ball cups 30, 42 when the ball cups 30, 42 rub against one another with very high pressure.

In order to carry out a movement such as this, the missile nose 6 has a first actuation means 44, within the supporting segment 40, with a motor drive that is not shown in Figure 2. In addition to the guidance means 28, the components of the actuation means 44 include a further element 46, which comprises a cylindrical guidance means 48 and faces the guidance means 28. On its side facing the guidance means 48, the guidance means 28 is likewise cylindrical, is concentric about the intersection point 32, and is provided with radial serrations. A toothed spur gear (which is not illustrated) on the guidance means 48 engages in these radial serrations such that the guidance means 28 can be guided in an up and down movement along the guidance means 48. This allows the guidance means 28 to be guided on a

segment of a circular path 50 about the pitch axis 36, and allows the nose tip 8 to be pivoted about the pitch axis 36. The guidance means 28 and the element 46 of the actuation means 44 are kept free of fluid-dynamic loads on the nose tip 8, which are transmitted to the supporting segment 40 from the nose tip 8 via the two ball cups 30, 42.

In addition to the actuation means 44, the supporting segment 40 has a further actuation means 52 with two elements 54, 56, which can move relative to one another. Analogously to the guidance means 28, the element 56 has radial serrations as guidance means, and the element 54 has an actuation motor with a toothed spur gear which can move the cylindrical guidance means of the element 56 to and fro, as indicated by the arrows 58. The element 56 is in this case mounted together with the nose tip 8 such that it can move relative to the element 54, and a guidance means for the element 56 is arranged concentrically both with respect to the intersection point 32 and with respect to the yaw axis 38, about which the guidance means of the element 56 can be moved on a circular path 60, whose centre point coincides with the intersection point 32.

The interaction of the two actuation means 44, 52 allows the nose tip 8 to be guided freely in two dimensions about the intersection point 32. The intersection point 32 in this case coincides with the hydrodynamic centre of pressure of the nose tip 8 and of the outer surface 16 which, by virtue of the conical shape of the outer surface 16, rests in a stable position relative to the supporting segment 40 in the cavity 18 during small movements of the nose tip 8.

The missile nose 6 is connected to the missile hull 10 via a schematically illustrated electric motor 62, by means of which the missile nose 6 is mounted such that it can rotate about the roll axis 34 relative to the missile hull 10. A rolling movement of the missile nose 6 such as this makes it possible to compensate for any rolling movement of the missile hull 10 during flight, and the missile nose 6 – and thus the sensor 22 – can be aligned with a flying target without any rotation about the roll axis 34. This allows a sonar sensor to provide particularly precise guidance to a target.

A further missile nose 64 is illustrated in Figure 3. Components which essentially remain the same in principle are numbered with the same

reference symbols. Furthermore, reference should be made to the description relating to the exemplary embodiment in Figures 1 and 2 with regard to features and functions which remain the same. The following description is essentially restricted to the differences from the exemplary embodiment in Figure 1 and 2. In order to move a nose tip 8 about a pitch axis 36, a bushing 24 projects into a supporting segment 40' and is attached by means of a guidance means 28', which is mounted in a groove in the guidance means 48', such that it can be moved to and fro at right angles to the pitch axis 36. The guidance means 28' is connected to a crank drive 66 with a ball joint coupling, which is itself connected to an electric motor as a drive unit 68. During a small rotational movement of the drive unit 68, the crank drive 66 is moved slightly onwards translationally, and draws the guidance means 28' translationally with it in the groove in the guidance means 48'. The two guidance beams 28', 48' are both curved and have a centre of curvature which matches an intersection point 32. During a translational movement of the guidance means 28' in the groove in the guidance means 48', the nose tip 8 is thus pivoted about the pitch axis 36.

The drive unit 68 is firmly connected to an element 56' which is mounted such that it can move in a groove in an element 54'. The element 56', analogously to the guidance means 28', is connected to a crank drive 70, which is in turn attached to a drive unit 72. During a slight rotational movement of the drive unit 72, that end of the crank drive 70 which is attached to the element 56' is forced to carry out a translational movement, and draws the element 56' (which is curved about the intersection point 32 in the same way as the groove in the element 54' and the guidance means 28') to and fro in a translational movement. In consequence, the drive unit 68 – and with it the crank drive 70, the guidance means 48', 28', the bushing 24 and the nose tip 8 – is pivoted about the yaw axis 38.

The drive unit 72 is attached to the casing 74 of the supporting segment 40' and can be rotated about a roll axis 34, together with the entire rest of the supporting segment 40'. A rotation such as this is driven by a motor by means of a drive unit 76, which is in the form of an electric motor and can rotate the supporting segment 40' relative to an attachment means 78 with the aid of a bearing 80, about the roll axis 34. The attachment means 78 is

used for attachment of the missile nose 64 to a missile hull, which is not shown in Figure 3.

A leaf spring (which, for the sake of clarity, is not illustrated) is arranged in the groove in the guidance means 48' in order to hold the nose tip 8 on the supporting segment 40'. This leaf spring presses the guidance means 28' in the direction of the attachment means 78 in the groove. In consequence, the nose tip 8 is drawn with a convex ball cup 30 into a concave ball cup 42 in the supporting segment 40', and is pressed against it. The nose tip 8 is mounted in a sprung manner in the concave ball cup 42. A leaf spring is likewise arranged in an analogous manner in the groove in the element 54', and presses the element 56' in the direction of the attachment means 78. The drive unit 68 is mounted in a single-sprung form and the nose tip 8 is mounted in a double-sprung form in this way, with the former being mounted such that it is sprung towards the attachment means 78 and the latter being mounted such that it is sprung towards the supporting segment 40' in the direction of the roll axis 34.

The schematic diagram in Figure 4 shows a method for steering the missile 4. The direction of the target 82 is found by means of the sensor 22, for example a sonar. The direction that is found is passed as an electrical signal to a first part 26a of the control unit 26, which is designed to calculate a direction of the target 82 relative to an axial direction of the missile nose 6, 64 which runs parallel to the roll axis 34. This calculation is carried out taking into account the instantaneous tilt of the nose tip 8 relative to the axial direction. A direction of flight change 84 is determined from the direction of the target 82 and is supplied via a subtraction element 86 (which will be explained further below) to a part 26b of the control unit 26 in the form of an autopilot. The autopilot uses the direction of flight change 84 to calculate a new tilt of the nose tip 8, which is implemented by means of drives, as described with reference to Figures 2 and 3. The target 82 is then detected again, and the direction that is found is once again passed to the part 26a of the control unit 26.

During the flight of the missile 4, in particular the missile hull 10 is subject to influences, in particular being struck by the surrounding water 88, such that the missile 4 and, with it, the missile nose 6, 64 as well are subject to accelerations which should also be taken into account in the calculation of

the tilt of the nose tip 8 in order to change the direction of flight. For this purpose, both the missile hull 10 and the missile nose 6, 64 have sensors 90, for example acceleration sensors or spin rate sensors, which detect and evaluate the instantaneous acceleration and pivoting rate of the missile hull 10 and of the missile nose 6, 64, respectively. The evaluated data is supplied to the subtraction element 86, which uses the data in conjunction with the calculated direction of flight change 84 to calculate a new direction of flight change 92, which is passed to the autopilot for implementation. On the basis of this new direction of flight change 92, the nose tip 8 is pivoted, with the sensor 22 also carrying out the pivoting movement of the nose tip 8 and now once again finding the direction to the target 82 from another viewing angle.

Reference symbols

2	Water surface
4	Missile
6	Missile nose
8	Nose tip
10	Missile hull
12	Motor
14	Cavitation bubble
16	Outer surface
18	Cavity
20	Outer wall
22	Sensor
24	Bushing
26	Control unit
26a	Part
26b	Part
28	Guidance means
28'	Guidance means
30	Ball cup
32	Intersection point
34	Yaw axis
36	Pitch axis
38	Yaw axis
40	Supporting segment
40'	Supporting segment
42	Ball cup
44	Actuation means
46	Element
48	Guidance means
48'	Guidance means
50	Circular path
52	Actuation means
54	Element
54'	Element
56	Element
56'	Element
58	Arrow
60	Circular path
62	Electric motor
64	Missile nose
66	Crank drive
68	Drive unit
70	Crank drive
72	Drive unit
74	Casing
76	Drive unit
78	Attachment means
80	Bearing
82	Target
84	Direction of flight change
86	Subtraction element
88	Water
90	Sensor
92	Direction of flight change

Patent Claims

1. Missile nose (6, 64) with a nose tip (8) which is mounted such that it can move relative to a supporting segment (40, 40') for supporting the nose tip (8) for steering along a trajectory, and having an actuation means (44, 52) for movement of the nose tip (8).

2. Missile nose (6, 64) according to Claim 1,
characterized
in that the actuation means (44, 52) is arranged within the supporting segment (40, 40').

3. Missile nose (6, 64) according to Claim 1 or 2,
characterized
in that the nose tip (8) can be pivoted relative to the supporting segment (40, 40') about at least one axis which runs through the nose tip (8).

4. Missile nose (6, 64) according to one of Claims 1 to 3,
characterized
by an attachment means (78) for attachment to a missile hull (10), in which case the nose tip (8) can be pivoted relative to the attachment means (78) about at least two axes which intersect at an intersection point (32) within the nose tip (8).

5. Missile nose (6, 64) according to Claim 4,
characterized
in that the intersection point (32) is located at the fluid-dynamic centre of pressure of the nose tip (8).

6. Missile nose (6, 64) according to Claim 4 or 5,
characterized
in that the actuation means (44, 52) has a first element pair with a first element (46, 54, 54') and a second element (56, 56'), with the second element (56') being mounted such that it can move together with the nose tip (8) relative to the first element (46, 54, 54'), and one of the elements (46, 54, 54', 56, 56') having a first guidance means (28, 28', 48, 48') for

guiding along the other element, and the guidance means (28, 28', 48, 48') being arranged concentrically with respect to the intersection point (32).

7. Missile nose (6, 64) according to Claim 6,
characterized
in that the actuation means (44, 52) has a second element pair which is arranged such that they can be moved at least partially by the first element pair, with a third element (54, 54') and a fourth element (56, 56'), with the fourth element (56, 56') being mounted such that it can move together with the nose tip (8) relative to the third element (54, 54'), and one of the elements (54, 54', 56, 56') having a second guidance means for guiding along the other element, and the guidance means being arranged concentrically with respect to the intersection point (32).

8. Missile nose (6, 64) according to one of Claims 4 to 7,
characterized
by a cavity (18) which is formed by the nose tip (8) with a rear outer wall (20) and a guidance means (28, 28'), which is attached to the outer wall (20), for movement of the nose tip (8), with the intersection point (32) being arranged in the cavity (18).

9. Missile nose (6, 64) according to one of Claims 4 to 8,
characterized
by a supporting means, which is arranged concentrically with respect to the intersection point (32), for absorbing fluid-dynamic loads of the nose tip (8).

10. Missile nose (6, 64) according to one of the preceding claims,
characterized
in that the nose tip (8) is mounted via a supporting means in the supporting segment (40, 40'), which is intended to transmit fluid-dynamic loads from the nose tip (8) to the supporting segment (40, 40') with moving elements (46, 54, 54', 56, 56') for movement of the nose tip (8) being kept free of fluid-dynamic loads on the nose tip (8).

11. Missile nose (6, 64) according to one of the preceding claims,
characterized
by a ball cup (30, 42) for supporting the nose tip (8).

12. Missile nose (6, 64) according to one of the preceding claims, **characterized**
in that the nose tip (8) has a conical outer surface (16).

13. Missile nose (6, 64) according to one of the preceding claims, **characterized**
in that the nose tip (8) is mounted such that it can pivot about three axes which intersect at an intersection point (32).

14. Missile nose (6, 64) according to one of the preceding claims, **characterized**
by a sensor (22), which is arranged within the nose tip (8) for flying target detection.

15. Missile nose (6, 64) according to one of the preceding claims, **characterized**
by a sprung bearing, which pulls the nose tip (8) towards the supporting segment (40, 40'), for the nose tip (8).

16. Method for steering a missile (4) with a moving nose tip (8) and with a sensor (22) for flying target detection, in which the nose tip (8) is moved in order to steer the missile (4), and the sensor (22) completes the steering movement of the nose tip (8).