

STRUCTURE OF FOLDING FINS FOR MISSILES AND THE LIKES

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

This invention relates to structure of folding fins for missiles, rockets, and the like, and in particular, to a cruciform folding fins for missiles, rockets and the likes stored and launched from tubular launchers from aircraft, ships, land vehicles where storage space is limited.

BACKGROUND OF THE INVENTION

Sub-sonic airborne vehicle, guided missiles, rockets or the like are often provided with long wingspan to increase lift and endurance. As the wings need to be stowed for easy storage and transportation before launching, the concept of foldable wing has been widely proposed, designed and employed, for instance, in the folding wings of the Penguin and Harpoon missile. Wings of more than eight inches in length will have problems storing within the limited space of a canister or even under the aircraft deployed with these missiles. This is because an envelope of a reasonable size is required in order to be mounted onto the aircraft. In view of the above, foldable wing structure for airborne vehicle or missiles, rockets or the likes are now a critical and essential feature in providing efficient aerodynamic lift, endurance and storage.

Fins of existing missiles and rockets are normally folded in either two methods - folding in the span-wise direction or in the body direction of the missile or rocket.

In the first method, fins are folded in the span-wise direction using spring and lock mechanism situated along the chord of the fins. An example of such a device can be found in the fins of the Harpoon missile. The wrap-around fins work on a similar principle with the curved fins wrapped around the body when in storage position. An example of such a mechanism is the Vikhr anti-tank missile.

The second approach is more commonly used for longer finned missiles or rockets where the fins are folded along the body direction thereof and lies within or flushed with the missile body, when in storage position. Examples of such existing missile systems are the Tomahawk Cruise missile and the Spike Anti-tank missile.

Various novel folding or collapsible fins have been proposed in the past for missiles and rockets, and the likes.

US Patent No. 4,858,851, filed June 7, 1988, issued August 22, 1989 to Steven A. Mancini and Joseph D. Kutschka describes a folding wing structure for a missile or other airframe comprising a leading edge strut assembly, and a double walled, pocket-like wing member of flexible fabric material which encloses the strut assembly. The struts are moveable between a collapsed, storage position in which they are substantially co-linear and an expanded position in which they project radially out from the missile. However, the foldable wing structure of US 4,858,851 is more suitable for triangular fins and for fins that do not have long aspect ratio (long span relative to chord length). The fins of the present invention will not be folded practically using such an approach due to the long aspect ratio.

Buckling will be significant resulting in the need for extra measures, in addition to those already mentioned in US 4,858,851, to resist buckling. Also, the complexity of the folding mechanism involved in US 4,858,851 will result in increased costs of manufacturing.

US Patent No. 5,356,094, filed March 4, 1987 issued October 18, 1994 to Rick Sylvain describes a foldable, multi-sectional air foil with apparatus enabling it to fold or curl up or down about the body of a craft; and to a system to maintain air foil rigidity during flight. The foldable wing of US 5,356,094 is suitable for crafts with 2 wings as can be seen from the examples in the specification. The folding of four fins like in the present invention using the approach of Sylvain will result in numerous overlapping round the missile resulting in a larger storage space compared to the approach claimed by the applicant. It is also to be noted that the invention of Sylvain applies to large cargo and passenger crafts such as cars and airplanes where the deployment of wings need not be in the region of milliseconds. Although there is no mention of the time taken for the wings of the Sylvain invention to unfold, it is understood that wings of such crafts take some time to deploy fully and there are no tested examples to show that such an approach to folding the wings can be applied to missiles.

US Patent No. 4,691,880 issued September 8, 1987 to Arthur M. Frank describes by means of a foldable missile wing deployable by means of an over center linkage powered by a torsion spring assembly capable of exerting a generally linear bias on the linkage over its full range of motion. Like in US 4,858,851, the approach to folding fins in the Frank

invention is not practical for fins with long aspect ratio like in the case of the present invention.

The conventional method of folding the fins in the span-wise direction has a severe disadvantage in that fins of relatively long aspect ratio (long span relative to chord length) cannot be folded practically in this manner. The second approach to fold the fins along the direction of the missile body may be used for longer aspect ratio fins. However, the four fins need to be stowed inside the missile such that the chord length of the fins cannot exceed the radius of the missile body and most importantly, space must be available to store the fins inside the missile body. Accordingly, it is an object of the present invention to provide a structure of folding fins for missiles or rockets, which overcome the above-mentioned limitation by folding the 4 fins such that they are folded and stored, flushed on the outside skin of the missile body. This approach has in fact been found practical and is used for glide/cruise missiles with two horizontal fins. An example is the AGM-154 JSOW glide bomb. However, there is no existing practical method to fold 4 cruciform fins using such an approach.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a structure of a folding fin for missiles, rockets or the like, wherein the structure is a relatively simple device allows folding of 4 cruciform fins alongside the missile body to minimize the storage space required by the

missile prior to launch from a tubular launcher, and to deploy the fins automatically when the missile is in flight. The deployed fins are arranged in a cruciform 'X' configuration employed by most skid-to-turn missiles.

A further object of the present invention is to provide a structure of a folding fin for missiles, rockets or the likes, wherein the fins of the missiles, rockets or the likes are stored, swept back and flushed to the surface of the missile body, thus in turns, enabling the missile to be launched from tubular canisters, usually used in artillery weapons and missile designs. After launch, the fins are deployed in such a way that the top fins are deployed earlier than the bottom fins by a small angle to avoid collision.

Yet another object of the present invention is to provide a structure of folding fins, wherein a gearing system is provided to the structure, which allows a measured amount of delay for the bottom fin, resulting in it being actuated slower for the first few moments, and consequently, the top fin swings forward faster, with the bottom fin following immediately behind.

Still another object of the present invention is to provide a structure of folding fins, wherein the fins are standard airfoils with special slots in the middle section to allow a locking mechanism to hold the top and bottom fins together in a cruciform 'X' configuration. The slots are half the chord length, with the entrance edges being tapered to allow smooth engagement. The mechanism is a positive locking mechanism to hold the bottom fin and prevent it from falling back due to aerodynamic forces.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be more clearly understood when considered in conjunction with the accompanying drawings, in which:

Figure 1 is a perspective view showing the missile fins and the body being in a storage position in accordance with the present invention.

Figure 2 is a perspective view showing schematically the missile fins and body in transient position as the fins are being deployed in accordance with the present invention.

Figure 3 is a perspective view showing schematically the missile fins and body at fully deployed position in accordance with the present invention.

Figure 4 schematically shows the front sectional view of the missile fins and body at storage position, showing the dihedral angle, θ and angle $\lambda = 90^\circ - \theta$, in accordance with the present invention.

Figure 5a shows the velocity profile for top fins upon deployment in accordance with the present invention.

Figure 5b shows the velocity profile for the bottom fins upon deployment in accordance with the present invention.

Figure 6 shows a sectional view of the actuation mechanism of the folding fins of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the drawings, a preferred embodiment of the present invention is illustrated and Fig. 1 is a perspective view of a missile or the likes with the missile fins folded and swept back and almost flushed to the surface of the missile body 20.

In accordance with the present invention, the folding structure comprises a pair of upper fins 11 and a pair of lower fins 12 and an actuation and locking mechanism 100 (referring to Fig. 6). As shown in Figs. 1 and 2, the upper fins 11 are provided with a slot 40 at the lower section of the fin 11 and the slot 40 is substantially perpendicular to the axial direction of the fins 11. The fins 11 are pivotally mounted onto the surface of the missile body 20 with a pivot peg 30 such that the fins 11 are moveable about the pivot peg 30. Similarly a slot 42 is also provided substantially perpendicular to the axial direction of the lower fin 12 in such a way that the slots 40, 42 located respectively on the upper fins 11 and the lower fins 12 interlock with each other, as shown in Fig. 3, which is a perspective view showing the missile fins 11, 12 are fully deployed.

In accordance with the present invention, the fins 11, 12 are deployed automatically when the missile is launched, as shown in Fig. 3. The two upper fins 11 are deployed earlier

than the 2 lower fins 12 to avoid collision. This is achieved by the actuation mechanism and locking mechanism 100 located inside the missile body 20 near the pivot peg 30, which allows a measured speed for the lower fins 12, resulting in them not being actuated as fast as the upper fins 11 for the first few moments. As a result, the upper fins 11 swings forward first, with the lower fins 12 following immediately behind. Fig. 2 is a schematic view showing the transient position as the fins 11, 12 are being deployed.

When both fins 11 and 12 have come to an end of the travel due to a mechanical stop (not shown), they are locked in place by the actuation gearing. Fig. 3 shows the fully deployed fins 11, 12 with the upper fins 11 set at a negative dihedral angle and the lower fins 12 at a positive dihedral angle of the same magnitude. The dihedral angle λ is defined as the angle of fully deployed fins 11, 12 measured with reference to an imaginary horizontal plane 50 of missile body 20. The dihedral angle λ at the fully deployed position is dependent on the pivoted position of the fins 11, 12 during the storage position. The angle that the pivot axis make with the horizontal plane 50, θ , dictates the dihedral angle λ , since $\lambda = 90^\circ - \theta$ (referring to Fig. 4). When all fins 11, 12 are fully deployed and intersect fully, the fins 11, 12 are locked in a cruciform 'X' configuration position by means of an actuation and the locking mechanism 100.

In accordance with the present invention, the fins 11, 12 are made of standard airfoils, but there are special slots 40, 42 on the fins 11, 12 to allow the upper and the lower fins 11, 12 to intersect with one another, as shown in Figs. 2 and 3. The slots 40, 42 are half the

chord length, with the entrance edges being tapered to allow smooth engagement of the fins 11, 12. The magnitude of the dihedral angle λ may be varied, by changing θ (the angle that the pivot axis make with the horizontal plane), such that the fully deployed fins 11, 12 have the desired aerodynamic characteristics in the imaginary vertical and the imaginary horizontal plane 50. Reducing λ would act to increase the aerodynamic vertical lift while reducing the aerodynamic side force and vice versa. In accordance with the preferred embodiment, this feature is useful as it allows the missile designer to adjust the aerodynamics of the system in the vertical and horizontal plane to obtain optimal aerodynamic characteristics.

In accordance with the present invention, the fins 11, 12 can be actuated by several actuating means, namely having separate actuators for each individual fin or having one actuator drive the upper fins 11 and another actuator drive the lower fins 12. The different arrangement of the mounting of actuating device brings into the system various other considerations like timing and actuation speed, requiring several feedback systems. The present invention will incorporate a common shaft 72 linking one actuator 60 to all four fins 11, 12 together. This ensures that the deployment is at the same instant, and is constant for all four fins 11, 12. The various speeds of the upper fins 11 and lower fins 12 will be addressed using a contoured bevel gear 71. The contours of the bevel gear 71 follow the profile of a spur bevel gear 70, which is eccentric in shape. The structure and function of the elliptical eccentric gear is known and can be found in prior art such as US Patent No. 6,293,884 dated 25 September 2001. However, in the present invention, the contoured bevel gear 71 is specially designed as the mating gear for the eccentric spur gear 70 and in the use of the contoured bevel gear 71 to vary the speed profile of the fin actuation. By varying the

immediate gear profile, the upper fin 11 swings out faster than the lower fins 12 due to the differences in speed (referring to Fig. 5). This is due to the instantaneous gear ratio at that point in time, which determines the speed and the gear ratio changes depending on the angular position of the spur gear 70 mating with the bevel gear 71 by virtue of the eccentricity.

The contoured gear profiles for the top and the bottom bevel gear 71 are 180 degrees out of phase (referring to Fig. 5). This allows the upper fins 11 to deploy at a high speed, while the lower fins 12 are at low speed. As the fins 11, 12 are still positively connected via the shaft 72, they will come to rest after deployment at the same position, removing the need for slip mechanisms or special timing algorithms for actuators.

The arrangement for the actuation and locking mechanism 100 can be seen in Fig. 6. As the actuator 60 is coupled to a worm gear 61, upon deployment, the fins 11, 12 will stay in place and not fall back as the worm gear 61 will prevent any reverse rotation of the fins 11, 12. This locks the fins 11, 12 into place once they are fully deployed. There are universal joints 62 between the driving shaft 72 and the eccentric spur gear 70 to bridge the difference in alignments.

In accordance with the preferred embodiment of the present invention, the four cruciform fins 11, 12 are folded in storage position prior to launching of the missile, and deployed automatically after launch into a cruciform 'X' configuration by means of an actuation and locking mechanism 100. There is no existing device used to fold the 4

cruciform fins, 11, 12 using such an approach. There is also no prior art describes the actuation mechanism and locking mechanism to deploy the fins 11, 12 automatically into a cruciform 'X' configuration.

While in the foregoing there has been disclosed a preferred embodiment in accordance with this invention, it should be understood that various changes and modifications can be made within the true spirit and scope of the invention as recited in the appended claims.

**CLAIMS**

1. A structure of folding fins for missiles or the likes, comprising
 - (a) a pair of upper fins pivotally mounted onto the surface of the missile body, and a slot being formed on the fins substantially perpendicular to the axial of the fins;
 - (b) a pair of lower fins pivotally mounted onto the surface of the missile body such that the lower fins are corresponding to the upper fins; wherein a slot is formed on the fins substantially perpendicular to the axial of the fins and is corresponding to the slot formed on the upper fins;
 - (c) an actuation and locking mechanism positioned within the missile body including a top and bottom bevel gear, an actuator, a spur bevel gear, a driving shaft and universal joints, thereby the actuation and locking mechanism allows the upper fins to deploy at a high speed while the lower fins are at low speed and upon fully deployment of the fins, a cruciform "X" configuration is obtained.
2. The structure of folding fins of claim 1, wherein the actuator is coupled to a worm gear so that upon deployment of the fins, the fins stay in play and not fall back.
3. The structure of folding fins of claim 1, wherein the fins are standard airfoils.



4. The structure of folding fins as set forth in claim 1, wherein the slots at the fins are slots of half chord length to ensure that the upper and lower fin intersect one another when fully deployed.
5. The structure of folding fins as set forth in claim 1, wherein contoured gear profiles for the top and bottom bevel gear are 180 degree out of phase.
6. The structure of folding fins as set forth in claim 1, wherein the fins form a pivot angle, θ of about 45° , to ensure that the fins are deployed with upper and lower fins close to right angles with each other.
7. The structure of folding fins as set forth in claim 1, wherein the actuation and locking mechanism lock the fins during storage, automatically swing open the fins during launch and lock the fins when fully deployed.
8. The structure of folding fins as set forth in claim 1, wherein the upper and lower fins are deployed at a different speed to ensure that they do not collide during deployment.