ABSTRACT

Thermal protection for the leading edges of supersonic vehicle control fins is provided by a coating of one or more layers of silica cloth impregnated with a phenolic resin and bonded to the control fin. The cloth is tightly woven with 70–80 percent of the fibers extending in the warp direction of the weave and is applied on the fin with the warp fibers extending parallel to the flow along the sides of the fin and perpendicular to the flow at the fin's leading edge stagnation line.

3 Claims, 2 Drawing Figures
SUPERSONIC VEHICLE CONTROL SURFACE HAVING A THERMALLY PROTECTIVE COATING

BACKGROUND OF THE INVENTION

This invention relates generally to control fins for airborne vehicles and more particularly to a supersonic vehicle control fin having a thermally protective coating over at least the leading edge thereof for insulating the fin against aerodynamic heating.

With the development of rocket motors capable of propelling airborne vehicles, such as guided missiles and ballistic missiles, at supersonic velocities, it has been found that aerodynamic heating of the control fins during supersonic flight produces heat intensities sufficient to melt many materials which are normally used for the construction of control fins, with the highest temperatures being produced along the leading edge of the fins. Excessive concentration of heat along the leading edge of the fin sufficient to destroy or deform the fin profile results in erratic guidance of the airborne vehicle and sometimes causes complete loss of control over the vehicle.

In the past, attempts to develop a control fin for a supersonic vehicle have generally followed one of three methods. One method, which utilizes the heat sink principle, merely employs a metal structure with enough heat capacity, the product of its mass and specific heat, to dissipate the absorbed energy within the structure without causing excessive temperature rise. But this method usually requires fin assemblies which are considered to be too heavy, particularly when high mach number trajectories are encountered.

Another disadvantage of the heat sink control fins is that, at high velocities, they experience localized melting of the metal fin along the leading edge of the fin which adversely affects the stability of the vehicle. A second approach to the problem has proposed the use of various high temperature metal alloys, such as the titanium alloys, for designing control fins which will operate at high temperatures, but it appears that such high temperature metal alloy fins are limited for use on vehicles traveling at speeds below mach 5 because the temperature limitations of the alloys are exceeded at higher velocities. The third approach to designing control fins that will operate at high temperature levels has involved the application of either a ceramic coating or a compression molded carbon and silica coating on the control fin. Ceramic coatings, which are intended to radiate a large portion of the thermal energy away from the fin and prevent large amounts of thermal energy to penetrate to the leading edge by conduction, are limited to very thin coatings since they crack and fail readily as thickness is increased, due to thermal stressing. Ceramic coatings are also expensive and do not tolerate structural flexing which is often severe on supersonic vehicle control fins. The molded carbon and silica compounds, which are intended to provide thermal protection by absorbing energy in the process of ablation, are also expensive to fabricate since they must be preformed and then bonded to the fin's leading edge, which in many cases may have a complicated configuration. Additionally, when the leading edge of the control surface is very thin, there is usually not enough reinforcement in the coating material to hold the material together when the molding resin degrades during stagnation heating and therefore the aerodynamic shear stresses acting upon the coating will tear apart the weakened portion of the coating along the leading edge.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a control fin capable of operating at high temperature levels such as those encountered at supersonic velocities.

Another object of this invention is to provide a temperature resistant control surface which is inexpensive to manufacture and reliable in operation.

Briefly, in accordance with one embodiment of this invention, these and other objects are attained by providing a metallic control fin with a thermally protective coating formed of one or more layers of tightly woven silica cloth having 70-80 percent of the fibers extending in the warp direction of the weave and being applied to the fin in such position that the warp fibers extend parallel to the flow along the sides of the leading edge of the fin.

BRIEF DESCRIPTION OF THE DRAWING

A more complete appreciation of the invention and many of the attendant advantages thereof will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is a side elevation of the tail portion of a missile having a control fin assembly mounted thereon; and

FIG. 2 is a sectional view of a control fin taken along lines 2-2 of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings wherein like reference characters designate identical or corresponding parts throughout the several views, and more particularly to FIG. 1 thereof, wherein the tail portion of a missile 10 is shown as having a plurality of metallic control surfaces or fins 12 mounted thereon at equiangularly spaced locations around the periphery of the missile just forward of the exhaust 13. Each of the control fins is provided with a thermally protective coating 14 which substantially covers the entire surface area of the fin projecting beyond the profile of the missile body. For ease of illustration, the control fins have been shown as flat rectangular members but it is to be understood that the thermally protective coating, to be hereinafter more fully described, may be applied to control fins having various configurations, either flat or curved about their longitudinal axis and having either vertical or inclined leading edges.

Referring now to FIG. 2, which shows an enlarged cross-sectional view of a thermally protected control fin constructed in accordance with a preferred embodiment of this invention, the fin 12 is shown as having a tapered forward portion 16 defining a thin leading edge 17 and having a protective coating shown generally at 18 which completely covers the tapered forward portion 16 of the fin and substantially covers both side
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walls of the fin. The protective coating is formed of one or more layers of tightly woven silica cloth which is impregnated with a suitable adhesive such as, for example, phenolic resin and bonded to the metallic fin. In the embodiment shown in FIG. 2, the protective coating consists of a first layer of preimpregnated silica cloth 20, which is wrapped around leading edge 17 and extends rearwardly along the side walls of the fin substantially throughout the length of the fin, and first and second overlays 22 and 24, respectively, applied thereon at the forward portion of the fin. Each overlay is constructed of tightly woven preimpregnated silica cloth and is bonded to its subjacent layer of silica cloth, the first overlay 22 being of such length as to partially cover the side walls of the fin when wrapped around the leading edge while the second overlay 24 only covers the leading edge.

The silica cloth, from which the protective layers 20, 22 and 24 are formed, is woven with 70–80 percent of the fibers extending in the warp direction of the weave and, to achieve optimum thermal protection, each of the layers is positioned upon the fin with the warp fibers extending in the direction of the arrows 26 and 28 so that the warp fibers are parallel to the path of fluid flow along the leading edge and along the sidewalls of the fin and are perpendicular to the leading edge of the fin. When the protective coating is applied in the ascribed configuration, aerodynamic heating of the fin assembly in flight may produce localized degradation of the resin in the cloth material in the vicinity of the leading edge of the fin, where aerodynamically induced heating is concentrated, and eventually the resin material may be consumed. However, the silica fibers remain intact and hold the protective coating together so that the metallic fin remains thermally protected. Aerodynamic shear stresses, which are particularly high in the region just downstream of the leading edge of the fin, will not rip the protective cloth apart since the fibers extend continuously from one side wall across the leading edge and along the other side wall and remain anchored firmly in virgin material along the sides of the control fin. Although intense heat concentrations along the leading edge of the fin, as may be experienced during sustained flight at very high mach numbers, may produce softening or melting of the silica cloth in the outer overlay 24 and perhaps even in the inner overlay 22, the metallic fin 12 will still be thermally protected by the innermost protective silica cloth coating 20.

Exemplary of a preferred thermally protected fin assembly, the silica cloth fabric is of the leached glass type silica and is tightly woven with 70–80 percent of the fibers extending in the warp direction of the weave. The fabric is impregnated with a suitable phenolic resin, such as, for example, Monsanto S/C 1008 resin, available from Monsanto, Inc., St. Louis, Missouri. The silica cloth fabric used for protective layers 20 and 24 is preferably of a thickness between 0.041 inches to 0.049 inches and a weight of 38 to 58 oz. per square yard; while the silica cloth fabric forming the intermediate coating 22 has a thickness of 0.019 inches to 0.025 inches and a weight of 17 to 28 oz. per square yard.

When applying the thermal protective coating to the metallic fin, which may be constructed of any suitable metal such as, for example, aluminum, the fin may be given a thin coating of standard primer, such as, HT 424F, available from Bloomingdale Rubber Company, Aberdeen, Maryland and dried for 30 to 60 minutes at 150°–250°F. The first layer of silica fabric 20 is then wrapped around the leading edge of the fin with approximately equal length portions extending over opposite sides of the fin and is applied to the fin carefully without wrinkling the fabric. The coated substructure is then placed in a vacuum bag and cured under 12 psi minimum differential pressure for 2 hours at 250°–285°F. The leading edge of the substructure may then be abraded and given a coating of the wet phenolic resin after which the first overlay coating 22 is applied to the substructure and the second overlay coating then applied over the first overlay over the leading edge. The assembly is then compression molded in place for 15 to 30 minutes at 250°–285°F under 25 psi minimum pressure. Finally, the coated fin assembly is cured at 285°F plus or minus 10°F for 6 to 8 hours. In positioning each of the three layers of silica cloth on the fin, each layer is positioned so that its fibers in the warp direction extend perpendicular to the leading edge and parallel to the flow along the side walls of the fin.

Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described herein.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A thermally protected control surface for supersonic airborne vehicles comprising:
   a metallic fin having substantially parallel side walls and an end wall forming a leading edge,
   a glass fiber woven fabric coating, having 70–80 percent of the fibers extending in the warp direction of the weave, attached to said fin with the warp fibers substantially parallel to the direction of flow along the sides of the fin and perpendicular to the flow at the leading edge stagnation line, and extending continuously from one side wall across the leading edge and onto the other side wall of said fin, to shield said fin against aerodynamic heating, and
   a curable phenolic resin impregnating and bonding said fabric coating to said fin.

2. The device of claim 1 wherein said coating includes:
   a first layer of said fabric covering said leading edge and substantially the entire surface area of each side wall,
   a second layer of said fabric attached to said first layer and covering said leading edge and the forward portion of said side walls, and
   a third layer of said fabric attached to said second layer and covering said leading edge.

3. The device of claim 1 wherein said fin is constructed of aluminum.