Implementation of vortex wake control using SMA-actuated devices

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ABSTRACT

Mitigation of the undesirable effects of trailing vortex wakes has been a long-standing priority for both reduction of submarine wake signature and alleviation of aircraft vortex wake hazard. A recent study established the feasibility of using relatively weak, secondary vortices with carefully selected unsteady amplitude and phasing to accelerate the breakup of the primary vortex system of a lifting surface, a technique denoted "vortex leveraging". This paper will summarize progress on the development of SMA-actuated devices for implementing vortex leveraging for hydrodynamic applications. The methods being applied to the hydrodynamic design of these deformable Smart Vortex Leveraging Tabs (SVLTs) will be described, and the results of a preliminary assessment of SVLT performance in achieving wake breakup will be presented. Also, previous work on the design and testing of deformable control surfaces actuated via embedded SMA agonist wires will be reviewed and the design process being employed in the present application will be discussed. Finally, the plans for near-term computational and experimental work to validate the use of SMA-driven devices for the wake mitigation task will be briefly outlined.

Keywords: shape memory alloys, vortex wake, wake mitigation, smart materials

1. INTRODUCTION AND MOTIVATION

Controlling the vortex wake of lifting surfaces has been a topic of considerable research in both the aerodynamic and hydrodynamic fields[1-6]. Candidate applications for wake control include minimizing the signature left by submarines (to enhance non-acoustic stealth) and to mitigate the safety hazard posed by the encounter of jet transports with the wakes of preceding aircraft. A previous paper[7] outlined the results of a basic feasibility study that describes a new approach to dealing with this problem and illustrates the important role of SMA-actuated devices in enabling this approach. The present paper will summarize progress to date on the further development of such devices - denoted Smart Vortex Leveraging Tabs or SVLTs - for implementing vortex wake control for hydrodynamic applications. The results of an assessment of projected SVLT performance will be presented here; computational modeling to date suggests that wake deintensification will be accelerated by a factor of three or more for representative submarine control surfaces. In addition, a discussion will be presented of previous work on the design and testing of deformable control surfaces actuated via embedded SMA agonist wires and the refinements and extensions of this work contemplated to support the present project. Finally, the plans for computational and experimental work to validate the predicted performance of SVLTs for the wake mitigation task will be outlined.

Reference 7 describes in some detail the possible applications of vortex wake control in both aeronautical and hydrodynamic applications. The primary focus of the present effort is on the latter, particularly on the rapid dissipation of the concentrated vortices trailed by submarine sailplanes; an illustration of a typical wake system produced by a submarine in cruise is shown by Figure 1. There has been considerable research both on assessing the strength of submarine vortex wakes and identifying passive and active methods to mitigate their adverse effects[6,8-10]. Not only are the noise and vibration due to wake ingestion in propulsors a concern, but the wake signature left by submarines both in cruise and during maneuvers is a significant issue in non-acoustic antisubmarine warfare (ASW).

Submarines in cruise typically generate a sailplane wake of considerable strength; typical operating practice is to run buoyant so that the submarine will rise rather than sink in case of loss of power or other malfunction. Thus, a steady download on the sailplanes is typically required to maintain depth control. This produces a vortex pair trailing from the sailplanes with self-induced upwash that will tend to cause it to rise to the surface. The interaction of this vortex wake with the surface may leave a detectable trail that would reveal the presence of the submarine. Achieving significant dissipation of the organized vortex wake is therefore an important aspect of preserving the stealthiness of the current submarine fleet.

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