On the Effects of Micro-Vortex-Generators on a Finite Wing in a Sonic Flow

על ההשפעות של מחוללי מערבולות זעירים על כנף סופית בזרימה קולית

A Master's Thesis Proposal

by

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1 Introduction

The quest of improving ones desired aerodynamic flow design parameters, has been initiated since the beginning of human flight. In order to try and accomplish this quest, the concept of flow-control devices has been established.

A flow-control device affects the original flow field, thus enabling controlling flow characteristics such as reduction of drag and separation zones. The flow-control devices fall into two main categories:

1. Active devices.
2. Passive devices.

The difference between the two categories is the usage of external energy source to control the desired flow characteristics (e.g. pumps, bleeds *etc.*). Practical requirements of flow-control techniques such as robustness, light weight and ease of implementation, tend to favor passive devices such as vortex generators (VGs).

The concept of using VGs, first introduced by Taylor [1] in the late 1940s, is based on increasing the near-wall momentum through the momentum transfer from the free-stream flow. He arranged a row of small plates/airfoils that projected normal to the surface at an angle of incidence, β, to the local flow which produced streamwise trailing vortices.

Further investigations were conducted, considering the effect on pitch-up and wing-dropping problems, buffet boundary, aileron effectiveness and airplane drag for a swept-wing fighter airplane at transonic speeds, via flight tests [2] showing positive results while noting no noticeable drag increase.

A newer approach suggests the usage of micro vortex generators (MVGs), whose height, h, is less than the boundary-layer thickness, δ, placed ahead of a region with adverse flow conditions. In addition to the effects on subsonic flows, MVGs have been also proposed as being able to improve the adverse effects caused by shock/boundary layer interactions (SBLIs) over transonic wings [3].

2 Research Objectives

In the proposed research, the effects of an array of MVGs, placed on a finite wing, subjected to supersonic flow will be investigated. The tested MVGs will be of counter-rotating vanes type, as were shown to be effective for a supersonic flow [1, 2]. A vanes type MVGs are shown in Figure 1.

The research will focus on the following subjects:

1. **Separation zone**: The detachment line distance from leading edge will be compared to the uncontrolled case. The attachment line and the total separation zone length will be compared as well.

2. **Drag**: Drag will be calculated for both controlled and uncontrolled solutions. A comparison of the drag due to lift for the controlled and the uncontrolled cases will be made.

3. **Pressure loss**: The pressure loss before and after the shockwave will be calculated for both cases. The total pressure loss of the flow (free-flow before and after the wing) will be compared.

4. **Flow stability**: Transient effects of the flow regime will be studied. Shock location distance from leading edge will be tested for static/quasi-static scenario.

5. **Flow regions**: The effect of the interaction between the lower and upper part flow domains of the wing on the shock/boundary layer interaction will be compared to that of a flow over an upper section of the wing (single domain).

The study will be conducted by solving numerically the flow equations (CFD), of a finite wing section (chunk) with periodic boundary conditions, using the proprietary program `EZNSS`. In order to eliminate turbulent-model dependence on the results, the solution will be solved using several well established turbulence models, while supplying an uncertainty factor (percentage) for the calculated flow characteristics.

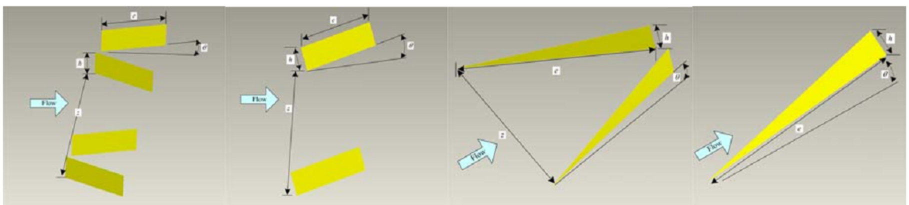

Figure 1: Vane configuration [3], co-rotating and counter-rotating.

References

[1] John C. Lin, *"Review of Research on Low-Profile Vortex Generators to Control Boundary-Layer Separation"*. Progress in Aerospace Sciences Volume 38, Pages 389-420. November, 2002.

[2] Norman M. McFadden,George A. Rathert,Jr. and Richard S. Bray, *"The Effectiveness of Wing Vortex Generators in Improving the Maneuvering Characteristics of a Swept-Wing Airplane at Transonic Speeds"*. National Advisory Committee for Aeronautics, Technical Note 3523, Ames Aeronautical Laboratory. Moffett Field, California. September, 1955.

[3] Frank K. Lu, Qin Li, Yusi Shih, Adam J. Pierce and Chaoqun Liu, *"Review of Micro Vortex Generators in High-Speed Flow"*. 49th AIAA Aerospace Sciences Meeting. Orlando, Florida. 4 - 7 January, 2011.