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Aeromechanics of Inflatable Airfoils

Andrew Simpson*, Michiko Usui†, Jamey Jacob‡ and Suzanne Smith§
Mechanical Engineering Dept.
University of Kentucky

The BIG BLUE (Baseline Inflatable Glider Balloon-Launched Unmanned Experiment) project at the University of Kentucky under a NASA Workforce Development Grant has a primary objective of promoting aerospace careers to undergraduate students. The goal of the project was to flight-test a high-altitude aircraft with inflatable/rigidizable wings to determine concept feasibility for a Mars explorer mission. The wings will be stowed in the fuselage, inflate during ascent, and rigidize with exposure to UV light. The vehicle will descend as a glider with only tail control. Ease of manufacturing is the primary design constraint in choosing the wing profile. Results from combined XFoil and ANSYS analyses on multiple profiles are presented. The E398 profile was selected and has been tested with ideal and inflatable profiles in a wind tunnel at flight conditions. Results from lift/drag tests are presented. A summary of future and current work on inflatable airfoils at the University of Kentucky is reviewed.

Nomenclature

c	Chord length of the wing
C_d	Drag coefficient
C_l	Lift coefficient
C_m	Moment coefficient
D	Drag of the wing
L	Lift of the wing
M	Mach number
$\mathcal{M}$	Moment of the wing about the 1/4 chord
Re	Reynolds number
S	surface area of the wing
V	Velocity of the vehicle
α	Angle of attack
μ	Absolute viscosity
ρ	Ambient atmosphere density
ν	kinematic viscosity

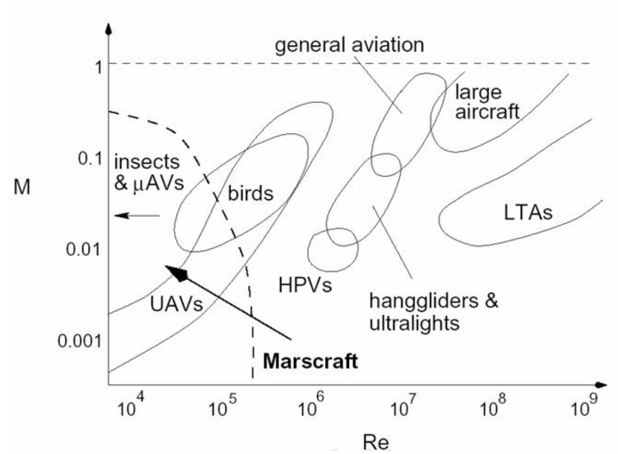

Fig. 1 Re versus Mach number

Introduction

Using unmanned airplanes to explore Mars[1] and Venus[2] is one of NASA's future exploration concepts. However, designing the airplane is difficult due to the low-density atmospheres and the cost of launch. Motivation for this research is to develop a low-density aircraft that can be evaluated at high earth altitude as a prototype Marscraft. Since Reynolds number (Re) is related to density, Marscraft must be designed for low-Re flight as illustrated in Figure 1.[3]

At low Re, flow over wings is uncertain. This leads to poor aerodynamic performance. To address this challenge, desingers typically increase wing span. However, for Marscraft, larger wing spans lead to increased launching costs. One possible solution is an aircraft with inflatable wings, provided inflatable wings can be designed to perform well at low-Re.

Marscraft efforts to date include flights of high-altitide rigid-wing gliders and of low-altitude inflatable wing aircraft. A NASA Ames[5] project conducted a successful flight test of a prototype Mars airplane. The eight-foot span rigid-wing glider was balloon-launched to 101,000 feet and released. A NASA Dryden[4] project tested an inflatable wing at low altitude. The skeleton of the wing was made of inflatable tubes, with crushable foam used to maintain the shape of wing. After the aircraft was released, the five-foot span inflatable wing was rapidly deployed, on the order of a third of a second, and completed a successful flight.

The University of Kentucky BIG BLUE project (Baseline Inflatable Glider Balloon Launch Unmanned Experiment) is in essence a combination of these two prior flight-test programs. ILC-Dover, Inc. developed an inflatable/rigidizable wing[6] that was used. The

*Graduate student, student member AIAA. *adsimp0@engr.uky.edu*
†Graduate student, student member AIAA. *musui0@engr.uky.edu*
‡Associate professor, senior member AIAA.*jdjacob@uky.edu*
§Associate professor, Associate Fellow AIAA.