On the Effects of Cathodic-Arc induced Jets on a profile subjected to a subsonic flow field

על ההשפעות של סילוני גז מקשתות קתודיות על פרופיל כנף הנתון לזרימה תת־קולית

A Master's Thesis Proposal

by

Anton Ronis

ID 314201005

Primary Thesis Advisor

Prof. Igal Kronhaus

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Faculty of Aerospace Engineering

Technion - Israel Institute of Technology

Technion City, Haifa 32000, Israel

1 Background

The quest of reaching one's desired aerodynamic flow design parameters has been initiated since the beginning of human flight. One of the many paths which tries to accomplish this quest, is the concept of aerodynamic flow-control.

A flow-control device affects the original flow field, thus enabling controlling flow characteristics such as reduction of drag by delaying and/or eliminating separation zones.

Several examples of flow-control devices include: bumps, vanes (vortex generators), synthetic jets, bleed injectors, plasma actuators and *etc.*

Cathodic Arc induced Jets

Recently [1], the characteristics of CAJs (Cathodic Arc Jets - gas flows generated by a cathodic arc, interacting with the molecules of the background gas) were experimentally measured in an atmospheric pressure environment.

This experiment is a continuation of a recent trend which deals with the application of plasma sources generated from a cathodic arc discharge for propulsion.

In [1], it is demonstrated that a CAJ pulse generated in an atmospheric environment, which is characterized by a time scale of hundreds of μs is capable of affecting the background still air by inducing a local flow field up to velocities of $\geq 100\ m/s$.

The jet direction was shown to be controlled by the application of an external magnetic field which affected the direction's rotation according to Lorentz force direction.

The results obtained in [1] suggest the possible use of a CAJ as a flow-control device.

2 Objectives

The proposed research contains two main objectives:

1. The modeling of a CAJ in respect to a background flow field.
2. Characterization of the effects of a CAJ on a 2D profile in a subsonic flow.

The first objective deals with creating and evaluating an empirical CAJ model. The model should behave well with available data from [1]. The model must deal with the flow properties of the CAJ, such as momentum, temperature, pressure and *etc*.

The second objective deals with characterization of the flow properties of a CAJ placed on a 2D profile subjected to subsonic flow, by using the model obtained in the first part of the research. The study will focus on core flow properties aspects, mainly:

1. **Drag**: The effects of the CAJ on drag will be calculated. A comparison of the drag due to lift will be analyzed.
2. **Stall Properties**: Stall properties will be analyzed in the form of stall angle.

3 Methodology

The research methodology is comprised of two aspects: creation of an empirical CAJ model and the application of this model in a flow field.

3.1 CAJ Model

A Cathodic-Arc-Jet empirical model will be constructed by data collected from [1]. This data-driven model will be then evaluated by comparing the simulated gas jets with the data obtained from [1]. The model will be realized as a numerical boundary condition in the flow solver.

3.2 2D Flow Field

A 2D set of Navier-Stokes equations (NS) containing the CAJ as a time lapsing boundary condition is solved.

A chosen RAS (Reynolds-Averaged Simulation) turbulent model which fits best to the evaluation test data will be used for the profile's flow properties study. Other models (*Spalart-Allmaras*, $k - \omega$ *etc.*) will be tested and accounted for by applying an uncertainty factor to the results. The tools used in the process are:

1. **Mesh Generation**: The numerical mesh will be generated by using `Pointwise`.

2. **Flow Solver**: The generated mesh will be numerically solved by using either a structured or unstructured grid solver (`openFOAM`/`SU`^{2}/`EZNSS`).

3. **Flow Visualization**: The resultant flow field will be visualized by using flow visualization programs (`ParaView`/`Tecplot`) and MATLAB.

References

[1] I. Kronhaus, S. Eichler and J. Schein, *"Schlieren characterization of gas flows generated by cathodic arcs in atmospheric pressure environment"*. Applied Physics Letters 104, 063507 (2014); doi: 10.1063/1.4865397.