Energy Audit of Active Flow Control Systems

Prof. A M Pradeep[1] and Kunal Tyagi[2,]

[1] Indian Institute of Technology Bombay,
Projct Guide e-mail: ampradeep@aero.iitb.ac.in
[2] Indian Institute of Technology, Bombay
Sophomore e-mail: tyagi.kunal@outlook.com

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ABSTRACT

Aims: It is known that active flow control systems produce a lot of changes in the flow which many time completely change characterisitics of the flow making comparison between different flow control systems very difficult. However, all the systems can be compared on the basis of their energy efficiency, i.e., the ratio of change in energy of the flow and the energy comsumed by the system to bring the change.
Methods: All the control systems typically consume the most energy during the control loop. Another significant portion of the energy in many systems goes towards manipulating the flow. Despite the different methods of energy consumption by the flow control systems, the energy consumed can be calculated. On the other hand, to calculate the energy dissapated/gained by the flow, we have to check what the control mechanism is , and the compute the energy change of the flow
Results: RESULT

Key words. energy audit – active flow

1. Introduction

The ability to manipulate a flow field to bring about a desired effect is of immense technological importance, as its potential benefits include savings in fuel costs, economically competitive and environmentally sound processes involving fluid flows. ((1))

Although passive flow control has been used aggressively in various fileds, active flow control has consistently remained in the back seat not due to ineffectiveness of the said method, but due to lack of reliable comparison between the different mechanisms, which differ completely in their method of flow control, yet give comparable results.

The motivation for his article is to investigate and categorise the different active flow methods and compare them using some set of relevant parameters.

With this aim the local, active flow control methods are investigated on the basis of energy auditing.

2. Active Flow Control methods

In this section the methods used by various active flow control systems will bew reviewed. Their performance characteristics will be rewritten in terms of energy input and consumption so as to facilitate easier categorisation and comparison.

Largely, the methods can be categorised by the following mechanisms:

– Cavity Oscillation control
– Transition Control
– Boundary Layer Seperation & Bubble Generation Control
– "On Demand" Vortex Generators
– Zero Net Mass Flux (Synthetic Jet) Actuators

3. Assumptions

The calculations are done considering the following assumptions:

1. Energy consumed by the mechanism excludes the energy required for feedback or feedforward loops, and includes the energy required to maintain or change the state of the mechanism.

2. Energy introduced into the flow is calculated considering the energy of vortices, flow, including energy losses due to turbulence, viscous friction, or other disturbances like bubble formation.

3. The calculations disregard the change in energy due to heat flow into or out of the mechanism and/or the flow.

4. Symbols

The following sections use standard and known symbols for as many quantities as possible, however, some symbols may differ depending on the context and requirement. An exhaustive list of the symbols used hereafter in Einstein's notation:

	Control surface
a_o	Speed of sound
c	span
C_D	Drag coefficient($\equiv 2D/\rho_\infty U_\infty^2 c; perunitspan$)
M	Mach number of the unperturbed flow
U	Flow velocity
X_0	Initial conditions; also Conditions at $x_i = 0$
X_o	Conditons outside boundary layer
X_u	Unperturbed flow conditions
X_p	Perturbed flow conditions
X_∞	Far-field, or ambient conditions
X_w	Conditions at the wall
X_{rms}	Root mean Square value
X_{in}	

5. Conclusions

1. The conditions for the stability of static, radiative layers in gas spheres, as described by Baker's ((2000)) standard one-zone model, can be expressed as stability equations of state. These stability equations of state depend only on the local thermodynamic state of the layer.
2. If the constitutive relations – equations of state and Rosseland mean opacities – are specified, the stability equations of state can be evaluated without specifying properties of the layer.
3. For solar composition gas the κ-mechanism is working in the regions of the ice and dust features in the opacities, the H_2 dissociation and the combined H, first He ionization zone, as indicated by vibrational instability. These regions of instability are much larger in extent and degree of instability than the second He ionization zone that drives the Cepheïd pulsations.

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