VIENNA UNIVERSITY OF TECHNOLOGY

INSTITUTE OF APPLIED PHYSICS

SURFACE SCIENCE

Bachelors Thesis

Title

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Contents

1 Theory

1.1 Formulary

Thermodynamics

Continuous one-dimensional flow

Thermal equation of state:

$$\frac{p}{\rho} = RT \quad \text{[term perf]} \tag{1}$$

Dynamic equation:

$$\frac{1}{\rho}dp + VdV = 0 \tag{2}$$

Speed of Sound:

$$a = \sqrt{\left(\frac{\partial p}{\partial \rho}\right)_s} = \sqrt{\gamma\left(\frac{\partial p}{\partial \rho}\right)_T} \tag{3}$$

$$a = \sqrt{\gamma\frac{p}{\rho}} = \sqrt{\gamma RT} \quad \text{[term perf]} \tag{36}$$

Mach Number:

$$M = \frac{V}{a} \tag{4}$$

Dynamic Pressure:

$$q = \frac{1}{2}\rho V^2 \tag{5}$$

$$q = \frac{\gamma}{2}pM^2 \tag{6}$$

From the dynamic equation and the speed of sound relation:

$$\frac{p}{\rho^\gamma} = \text{constant} = \frac{p_t}{\rho_t^\gamma} \quad \text{[isen, perf]} \tag{34}$$

From which:

$$\frac{p}{p_t} = \left(\frac{\rho}{\rho_t}\right)^\gamma = \left(\frac{T}{T_t}\right)^{\frac{\gamma}{\gamma-1}} = \left(\frac{a}{a_t}\right)^{\frac{2\gamma}{\gamma-1}} \quad \text{[isen, perf]} \tag{35}$$

Combining the above equations gives Bernoulli's equation for compressible flow:

$$\frac{\gamma}{\gamma-1}\left(\frac{p_t}{\rho_t}\right)^{\frac{\gamma-1}{\gamma}}\left(\frac{p}{p_t}\right)^{\frac{1}{\gamma}} + \frac{V^2}{2} = \frac{\gamma}{\gamma-1}\frac{p_t}{\rho_t} \quad \text{[isen, perf]} \tag{36}$$

Usefull Ratios

$$\frac{T}{T_t} = \left(1 + \frac{\gamma-1}{2}M^2\right)^{-1} \quad \text{[adiab, perf]} \tag{43}$$

$$\frac{p}{p_t} = \left(1 + \frac{\gamma-1}{2}M^2\right)^{-\frac{\gamma}{\gamma-1}} \quad \text{[isen, perf]} \tag{44}$$

$$\frac{\rho}{\rho_t} = \left(1 + \frac{\gamma-1}{2}M^2\right)^{-\frac{1}{\gamma-1}} \quad \text{[isen, perf]} \tag{45}$$

$$\frac{a}{a_t} = \left(1 + \frac{\gamma-1}{2}M^2\right)^{-\frac{1}{2}} \quad \text{[adiab, perf]} \tag{46}$$

1.2 Foundational principles

Idealized flow regimes

Turbulence

Mach regimes

Dimensionality of the flow

2 Analytical work

2.1 Scope and objectives

Geometry and components

The geometry can be explained in three simple sections: gas from a reservoir (1) flows over a duct into the reactor (2) where it leaves through another duct into a vacuum (3). This is a stark simplification, but for a great part of this thesis, this is how we will imagine our flow path. This is because the only important thing we left out is any kind of leaks in the system. Those leaks will be most influential around the reactor, since this is the only part not held at a constant pressure by any external part of the system.
We will now get into the specifics about all the important parts of the system:
Inlet Reservoir
It is held at a constant pressure P_0 and a constant temperature T_0 and contains only one gas which is defined by its specific heat ratio γ and by its molar mass M_m. These are all parameters which are set by us in advance. None of these will change throughout a calculation and are to be decided in advance.

Motivation and goals

2.2 Framework for Analysis

Important assumptions

Regions of interest

Limits of the theory

2.3 Analytical Descriptions

3 Discussion

4 Conclusion

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