DESIGN OF A LANGMUIR PROBE FOR AN EXPANSION TUBE FACILITY

Motivation & Objectives

To design vehicles moving at hypersonic speed such as re-entry capsules, the thermal flux issuing from the complex reactive and radiative flow have to be computed. The shock wave generated ahead of such a vehicle is so strong that the gas is ionised in a significant way.

Two flow conditions were investigated during this project. The first one simulates an entry flow at supersonic velocity (6 km/s) into Titan atmosphere (96% CO\textsubscript{2}, 4% N\textsubscript{2}), using the X2 facility in the non-reflected shock tube mode. A thin wire probe was embedded in the body of a Pitot probe to investigate this condition.

The second case simulates an entry flow (8.5 km/s) into Mars atmosphere (96% CO\textsubscript{2}, 4% N\textsubscript{2}), using the X2 facility in the expansion tunnel mode. Two sets of probes were embedded on the cylinder model. The first set was protruding 2 mm into the flow and the second was flush mounted.

Flow to be investigated

The signals obtained with the Langmuir probes exhibited strong voltage amplitudes and low noise comparatively with the main signal. The response of the probe to the incoming shock wave was extremely well synchronised with the Pitot probe signal (pressure sensor).

The signals were used to determine the electron density.

A reasonable temperature of approximately ten times the bulk gas temperature (computed assuming chemical equilibrium) was found for Titan condition. A temperature of the same order of magnitude for Mars condition was found. The flush mounted probe (Mars condition) could not be used (technical problem). No significant difference was observed between the two methods used.

All methods developed were implemented to compute the electron density. The highest density found for Titan condition is close to the density computed assuming chemical equilibrium. For Mars condition, the density found is two orders of magnitude lower.

The difference between all methods used was slight for Mars condition.

Some of the reactions present in the flow, such as electron impacts ionisation, are directly dependant on the electron temperature and density number, also, transport parameters associated with electrons, such as electron thermal conductivity for example, can have a significant influence on the flow.

The electron temperature and density are therefore of interest for the computation of reactive and radiative flux.

The goal of this project was to investigate these two parameters by an experimental technique called the Langmuir Probe.

The Langmuir probe comprises a wire inserted into the gas under investigation. An electrical potential is applied to the probe. If the potential is slightly negative, then the most energetic electrons can reach the probe and diminish the total current to the probe. The electron current is then proportional to \( e^{-e|V|/kT} \), which is used to determine the electron temperature.

To study a rapidly varying gas such as encountered in the X2 facility, the Triple probe method was used. Very rapid variations in the flow can be measured with this method (\( \tau_{p/e} \)). The original method assumes that \( I_{p/e} \) is constant on each tip of the probe, which is an approximation.

To increase the accuracy of the method, several modifications were implemented.

- Modified unified theory method, using theory, graphically.
- Corrected method, using\( I_{p/e} = \text{const} \), which is an approximation.
- \( I_{p/e} = \text{const} \), which is an approximation.
- Corrected method, using \( I_{p/e} = \text{const} \), which is an approximation.
- \( I_{p/e} = \text{const} \), which is an approximation.
- \( I_{p/e} = \text{const} \), which is an approximation.

Finally a simple method using \( I_{p/e} = \text{const} \), which is an approximation.


deduce the electron density was used to compare the results.

Results

Acknowledgements

Carolyn Jacobs, Troy Eichmann & David Gifford / The University of Queensland
Christophe Heiland & J-L Dorier / CRPP