AN OBSERVATION OF FILM THICKNESS AND LOCAL PRESSURE IN UPWARD AND DOWNWARD ANNULAR TWO-PHASE FLOW IN MICROGRAVITY, HYPERGRAVITY AND NORMAL GRAVITY

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ABSTRACT

The phenomenon of two-phase flow in a near weightless environment (or microgravity) is becoming increasingly important. Two-phase flow loops are used in advanced spacecraft thermal management systems and also occur during the transfer of cryogenic propellants. On earth, two-phase annular flow is common in power plants and many chemical processing plants. The liquid film along the tube wall plays a large role in mass and momentum transfer, featuring a complex wave structure. It is the wave structure phenomenon relating to the pressure and film thickness time trace that is the current interest in this investigation.

Film thickness and local pressure time trace measurements were taken in normal (earth gravity) and microgravity (µ-g) conditions during the 29th and 30th Annual European Space Agency parabolic flight campaign operated by Novespace in Bordeaux, France. A high sampling rate and measurement accuracy are essential for a sufficient representation of the film thickness. The parallel wire conductance probe, initially used by deJong (1999), measures the electrical conductance between two wires stretched across the flow. Annular flow film is highly dynamic and hence the film thickness and associated local pressure fluctuate rapidly. The instruments require high frequency response and minimum damping. The Druck PDCR 900 pressure transducer has a frequency response quoted by the manufacturer to be 0 to 20000 Hz. Local pressure taps were placed in the same horizontal plane as the film thickness probes, perpendicular to the wires. It is essential that the local pressure measurement not interfere with the film phenomena, and as such the measurements were made at the tube wall.

An investigation into upward and downward annular flow at earth’s gravity was made by Ariyadasa (2002) in a 9.925 mm diameter tube. The primary interest of this investigation was the relationship between the pressure and the film thickness. An investigation was made by Moe (1991) that examined the film thickness and pressure time traces in a horizontal flow. Moe observed the relationship between pressure peaks and film thickness peaks in a horizontal flow and indicated that the pressure differential might be enough to exert a significant force on the waves. Webb and Hewitt (1975) observed the pressure peaks that accompanied and lagged the film thickness peaks. They concluded that the time delay exists because of interaction with the exit condition of the system.

Based on the time traces of the film thickness and localized pressure obtained from available data, the relationship between the film thickness and the pressure under the wave appear to indicate some correspondence. Comparison of the time traces consisted of considering the film thickness greater than one standard deviation from the mean over the 4 or 8 second window. In

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this region, if the film thickness time trace was increasing or decreasing as the local pressure was increasing or decreasing, the relationship was observed. Classification using nearly 100 microgravity, hypergravity and normal gravity annular flow data points was performed.

A typical film thickness and local pressure time trace for an upward annular flow at normal gravity conditions are featured in figure 1a. The liquid superficial velocity is 0.24 m/s and the gas superficial velocity is 20 m/s. Featured in figure 1b, is a flow image in the same tube diameter.

![Figure 1](image-url)

Figure 1: (a) Film thickness (solid line) and local pressure (broken line) time traces at normal gravity; (b) Annular flow image at normal gravity (Vsl = 0.24 m/s, Vsg = 19.5 m/s, P = 99.3 kPa)