Lab Report 2: Shock Wave Analysis

Nathaniel L. Holmes

North Carolina State University, Raleigh, NC, 27607

**Nomenclature**

= atmospheric pressure

= stagnation pressure before shock

= static pressure before shock

= stagnation pressure after shock

γ = specific heat of fluid

M = Mach number

1. **Introduction**

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HIS document is a report on the second MAE 352 lab in the Spring 2019 semester. Pictures were taken of shockwaves using the Schlieren system, and the aim of the lab was to analyze the shockwave images to calculate the shock angle. The block number and wedge angle were recorded for each run, during which twenty photos were taken. Block number and wedge angle values were varied between tests to provide a set of data to be compared to the theoretical data set. MATLAB was used to process all images and create the plots.

1. **Calculations**
2. **Mach Number by Block Number**

The pressure readings taken from the transducers in the lab do not account for the atmospheric pressure, which is recorded separately. For accurate calculation of Mach number, the atmospheric pressure, , was added to all other pressure readings, which includes . This basic addition is shown for the stagnation pressure before the shock below to serve as an example. These total pressure values were used to make the calculations for Mach number, but the subscripted is only present here to distinguish it from the pressure reading Note that in later calculations, the additional subscript is dropped and is used to refer to the new value.

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|  |  | (1) |
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1. **Mach Number by Theta-Beta-Mach Relation**

The first method of Mach number calculation was with the use of the isentropic relation equation below.

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|  |  | (2) |

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1. **Data and Results**

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| **Figure 1. Quadratic Regression of Mach Number Data.** *The quadratic regression ignores the first two points of each data set. In addition, error bars are displayed along each of the 100 evenly-spaced points used in the regression. Magnitude of the bar at each point is equal to the difference of the method regression values.* |

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| **Figure 2. Cubic Regression of Mach Number Data.** *The cubic regression also ignores the first two points of each data set. Again, the error bars are displayed in the same fashion. Note that the coefficient of the leading term is smaller than before.* |

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| **Figure 3. Quartic Regression of Mach Number Data.** *The quartic regression follows the same format as the other two plots. Note that the leading term coefficient is much smaller than that of the quadratic regression.* |
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1. **Discussion**

Knowing that the supersonic wind tunnel at NCSU has the capability to operate between Mach numbers of 1.5 and 3.5, it can be noted that the Mach numbers from both methods of calculation are reasonable values as they fall within the range. As the block number increases, the nozzle in the wind tunnel widens, and therefore should reflect a decrease in Mach number due to the reduced speed of the flow. This idea also reinforces the validity of the experimental values as the plots display that higher block number results in lower Mach number.

The first two and a half seconds of each wind tunnel run were excluded from the data set to account for the time the flow requires to gain stability. The remainder of the values at each block number were then averaged and converted from pounds per square inch to Pascals. One-hundred equidistant values were used when calculating the regressions for both the isentropic and Rayleigh methods, but the first two data points from both sets were excluded from the range as the flow did not appear to have gained stability at that block number.

The isentropic method overall yielded slightly lower Mach numbers at every point, but this difference is only very slight, as can be seen in Table 1. The regression values did not differ by even one percent, though when high Mach numbers are concerned, one percent may cause drastic impacts. The isentropic method makes an idealistic assumption that the flow does not generate entropy, when in reality it does, however, the amount of entropy may be insignificant. The Rayleigh pitot tube method however does not make this assumption and accounts for the pressure after the shockwave. While the irreversibility in the flow is likely negligible, the results of the Rayleigh equation are more reliable.

The lack of stability could be explained by the limitations of the wind tunnel. At block number 600, it is reasonable that the flow would exceed a Mach number of 3.5, which is the maximum that the wind tunnel can support. Shown in each figure is the equation for its regression. Each regression has a small leading term, but this is especially true for the cubic and quartic regressions. As the block number to Mach number relationship is not linear, it is likely quadratic in nature, and therefore the data set is best represented by the quadratic regression shown in Fig. 1. Even if the Mach number limitation is only approached by block number 600, it is possible that the data may be somewhat inaccurate unless given more time to stabilize.

1. **Appendix**
2. **References**

1Narsipur, Shreyas. “MAE 352 – Experimental Aerodynamics II General Information and Lab 1 (Supersonic Wind Tunnel Block Calibration)”. *NCSU,* January 2, 2019.