Simulation and Visualization of Elementary and Potential Flows

The City College of New York

Dept. of Mechanical Engineering

ME 57200, Aerodynamics

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## Abstract

This project presents a user-friendly MATLAB code able to simulate basic potential flows in 2D. If it can be simulated, it will allow better intuitive connections between the equations and the visualization. After the basic potential flows can be displayed in MATLAB, multiple flows will be able to be visualized, if the code allows the potential flow functions to satisfy Laplace’s Equation, which should make the simulation of multiple flows much easier. Implementing a GUI will make interactivity much easier, along with the use of animations to better visualize the flow direction and behavior.

## Nomenclature

## Introduction

The potential flows that were covered in ME 57200: Aerodynamic Design set the foundation of most analytical flow analyses. From basic flows such as uniform, source, sink, and vortex flows, we can obtain stream functions and streamlines, which define the flow path of particles affected by such flows. Such derivations can lead to more complex flow patterns.

Firstly, let us examine some the elementary flows. Uniform flow is defined by velocity at a given angle from the horizontal. This can be thought of as , the free stream velocity. The streamlines are simply straight lines, with the direction defined by the angle. The cartesian velocities are shown in **Equation 1**.

|  |  |  |
| --- | --- | --- |
|  |  | *(1)* |

Source flow is defined by , the strength of the point source. The cartesian velocity components are shown in **Equation 2**. Sink flow utilizes the same velocity equations but is defined with a negative strength.

|  |  |  |
| --- | --- | --- |
|  |  | *(2)* |

In the case of streamlines, they originate from the source outwards. The opposite occurs for sink flow, thus the negative strength.

Vortex flow is defined by , the circulation. **Equation 3** shows the cartesian velocity components for vortex flow, which look similar to that of source/sink flow.

|  |  |  |
| --- | --- | --- |
|  |  | *(3)* |

With these components established, we can combine multiple flows. Usually, these flows are defined by and , the stream function and potential function, respectively. However, through the *Laplace Equation*, shown in **Equation 4**, the combination of velocity components is allowable, as long as the flow is steady-state, incompressible, and irrotational.

|  |  |  |
| --- | --- | --- |
|  |  | *(4)* |

The *Laplace Equation* can be proved to work with the stream function as well. Additionally, the *Cauchy-Riemann Equations* allow us to relate the stream function and potential function with the cartesian velocity components. These are shown in **Equation 5**.

|  |  |  |
| --- | --- | --- |
|  |  | *(5)* |

By taking the partial derivates with respect to x or y of the stream or potential functions of the elemental flows, we can obtain the cartesian velocity components shown in **Equations 1, 2,** & **3**.

## Methodology

Explain MATLAB, gridmesh, functions, definitions for different elementary flows, quiver and streamline plot, possibly animation.

## Results

Show quiver and streamline plots for uniform, source, sink, vortex. Show combination (Rankine Oval, Doublet, Non-lifting flow over cylinder, random placements).

## Discussion

Discuss successes, challenges, improvements. Mention future work and GUI functionality.

## Conclusions

Conclude project, lessons learned, experience gained.

## References

1. Professor Yang Liu’s ME 572 Lecture Notes
2. <https://potentialflow.com/flow-elements>
3. <https://web.mit.edu/16.unified/www/FALL/fluids/Lectures/f15.pdf>
4. <https://web.mit.edu/16.unified/www/FALL/fluids/Lectures/f16.pdf>

## Appendix A