Laminar Fluid Flow in Non-Circular Pipes

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Abstract:
The properties of laminar fluid flow are well understood in the context of circular pipes, but they have not been compared to the laminar flow properties for pipes of a non-circular shape. These comparisons have applications for space saving and efficiency increases in architecture, engineering, and even medicine. Half pipes of a circle and square with uniform cross sections were constructed with PVC piping and sheeting and filled with corn syrup. Aluminum foil squares were suspended in the corn syrup and their movements were observed. The flowing syrup was captured in digital video and then run through video analysis to determine flow rates for various points. This analysis allows for fluid and energy transfer calculations and comparisons to be made between the differently shaped pipes, allowing for analysis of pipe shape efficiency as a whole.

Methodology and Circular Trial
• One end of the half pipe was tipped upwards
• Corn syrup flows in one direction, taking the aluminum squares with it.
• Video collected and imported into the LoggerPro software.
• Frame by frame tracking found the positions and movements of the aluminum foil squares over time.

Square Half Pipe Trial
The same data collection method was used for the square pipe, but the relationship between the speeds of the aluminum squares and their position was unknown.
• Applying Poiseuille’s equation to the square half pipe proved to be false.
• Speed vs distance from short side and speed vs distance from long side, shown below, show only weak correlation values for the linear fits, not nearly enough to imply causation.

Experimental Setup
• PVC half pipes were filled with corn syrup
• Aluminum squares were suspended at various intervals and depths.

Conclusions
Our preliminary trial for the circular half pipe yielded excellent results, fitting very closely to known data and relationships, lending confidence to our methods of analysis.

Fluid flow within the square half pipe showed that along a given rectangular ring around the center point fluid speed varied immensely. Fluid flow within the square half pipe also did not function like that of the circular pipe which flowed in concentric rings. Instead fluid flow appeared to occur in a modified version of what happened within the circular pipe. While distance from the center was still a primary factor, this relationship deteriorated near the edges of the pipe, where fluid flow reached 0 no matter how far away from the center the edge was. This relationship of speed and position was best modeled using the product of distances from each side.

The increased perimeter of the square half pipe, as well as the great speed loss near the edges, end up making total fluid transfer slower within the square half pipe as compared to the circular half pipe. Therefore, in terms of fluid and energy transfer, the circular half pipe has turned out to be better in terms of efficiency. This bring said the square half pipe still allows for decent fluid transfer and could be used in space saving applications, although our data is not complete enough to make conclusions about those possibilities at this time.

Future Goals
Our future goals for this project include collecting data and doing analysis on a triangular half pipe and another polygon (hexagon being the most likely), reanalyzing tests on specific points of interest for the square and circle half pipes, and attempting to analyze space to fluid flow efficiency.