

Analysis of fluid mechanics structures using three-dimensional printing techniques

By: Onkar Chander, Undergraduate,
Faculty of Engineering,
Department of Mechanical Engineering
Supervisor: Dr. Catherine Mavriplis

Overview

Fluid mechanics structures are difficult to visualize and understand by only using limited two-dimensional representations. The purpose of the research is to utilize data acquired from computational fluid dynamics (CFD) software to formulate three-dimensional models of fluid flow at various time intervals. Data acquisition (numerical data of the flow), processing (file types), and implementation (using 3D printers) steps are used to create the desired 3D models. The objective is to obtain a functional STereoLithography (STL) file using the flow data. This file format is recognized by all 3D printers and is required to print the desired fluid structure layer-by-layer. Modifications needs to be made to assure the complex structure has a volume and is supported when printing. Ultimately, the research integrates the use of CFD, and computer-aided design (CAD) software to print complex structures of fluid flow, such as shedding vortices for flow past a cylinder. The results from this research will provide an enhanced understanding of the flow to students and serve as educational tools for in-class learning.

Methodology

Fluid mechanics structures are complex in geometry and therefore can take up a lot of memory on computers. The process to obtain a 3D print of the flow requires four steps (outlined below). A brief overview of the key facts of each step are also stated.

1) Preliminary Research

• 3D printing is an Additive Manufacturing (AM) process which can create very complex solid or hollow structures by laying down successive layers of material until the entire object is created

2) Data Collection & Formatting

• Data for flow past a square cylinder using computational fluid dynamics (CFD) software is provided and then opened in ParaView (visualization package for CFD) where the flow is then optimized by varying parameters to be viewed

3) Data Processing

• Once the desired flow simulation is viewed in ParaView it must be converted into an STL (STereoLithography) file; this is the required file type for all 3D printers

4) Printing

• The STL file of the flow is imported into SolidWorks (SW) where it is recognised as a solid body or surface which makes the STL file editable. SW allows user to save the edited flow simulation into an STL file. The file is then imported to the MakerBot 3D printer software and exported as a .x3g file for the Replicator 2 printers at the uOttawa Makerspace.



Figure 1. Two-dimensional view of flow past a square cylinder exhibiting vortex shedding



Figure 2. 3D Printer

Results

Once the desired flow to be printed is obtained in ParaView, the current view (at chosen time step) is processed as a STL file. It is important to note primary data types used in ParaView are 'meshes'. These meshes are represented by five types of data grids, however we are only interested in polygonal grids—composed of points, lines, and 2D polygons. Connections between cells can be arbitrary or non-existent. An STL or commonly referred to as a Standard Triangulation Language file is a widely-used type of 3D model file. It consists of surfaces made up of many triangles. The printer reads the STL file and slices the 3D model into layers. This process is accomplished by the 3D printer software. The file types include: GCode, .makerbot, X3G and S3G. These files have toolpath profiling files containing instructions for 3D printers. The file is then loaded into the 3D printer and the process is complete.

Vortex Shedding

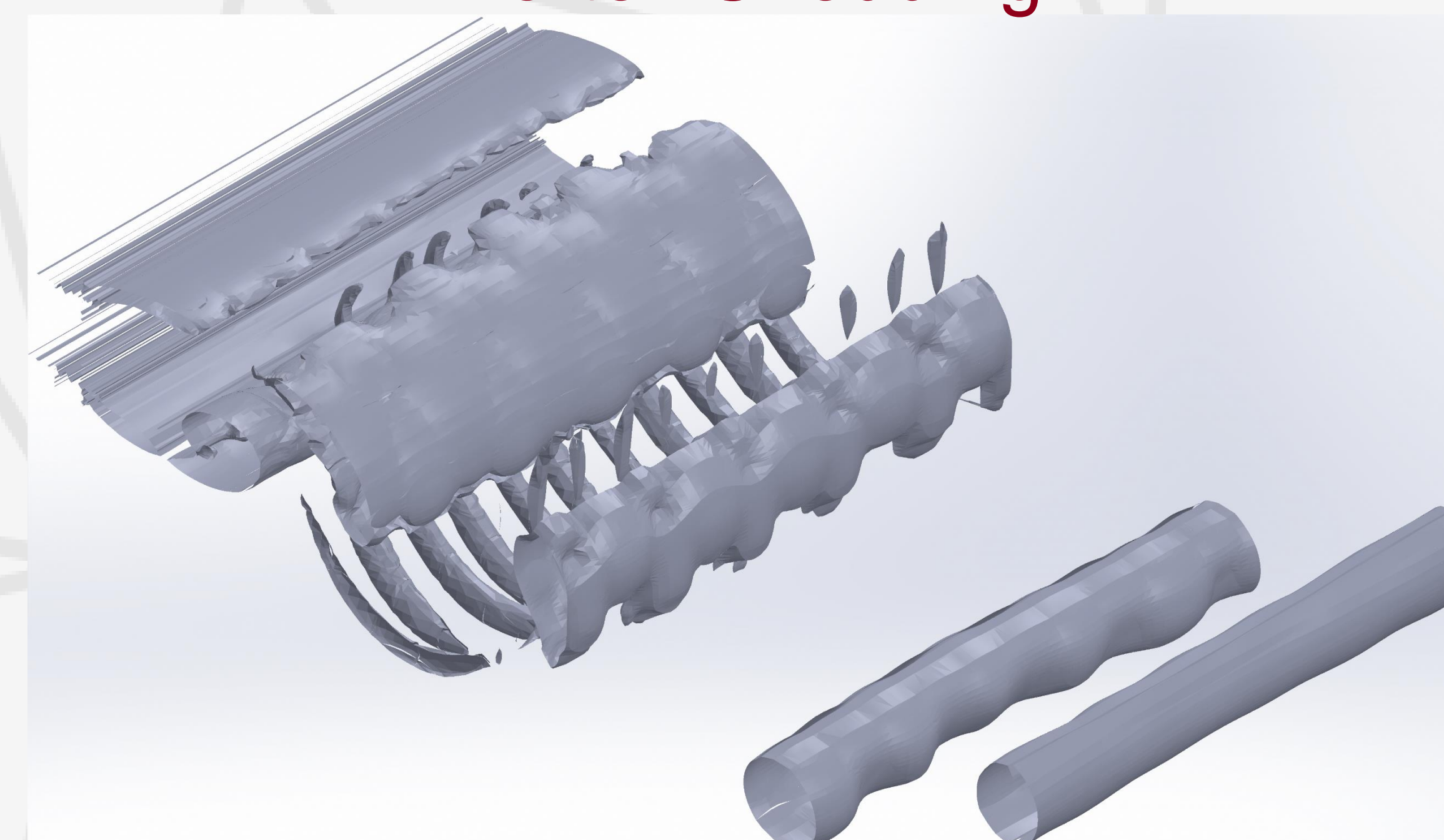


Figure 3. Three-dimensional computer model of flow past a square cylinder exhibiting vortex shedding

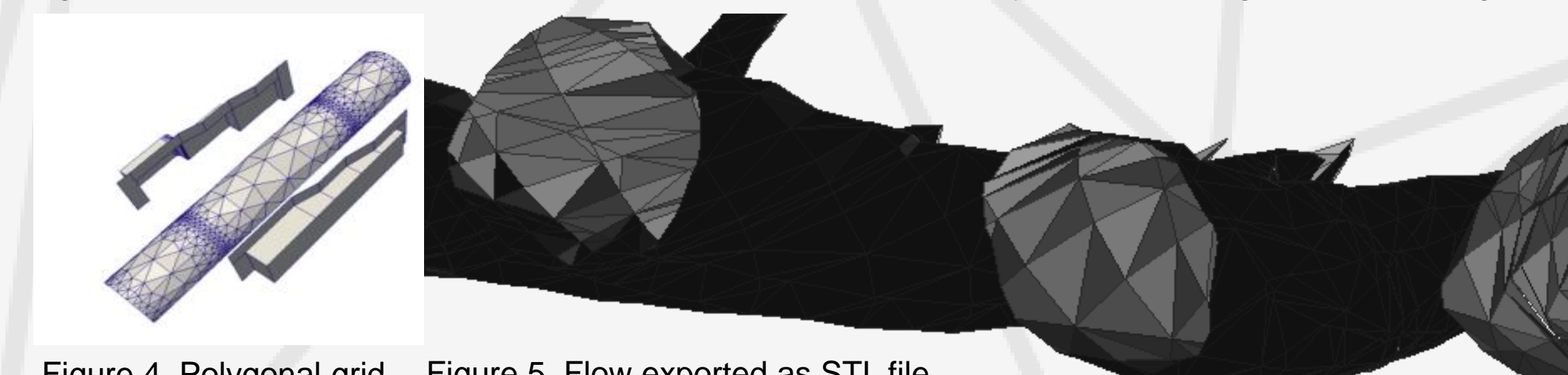


Figure 4. Polygonal grid Figure 5. Flow exported as STL file

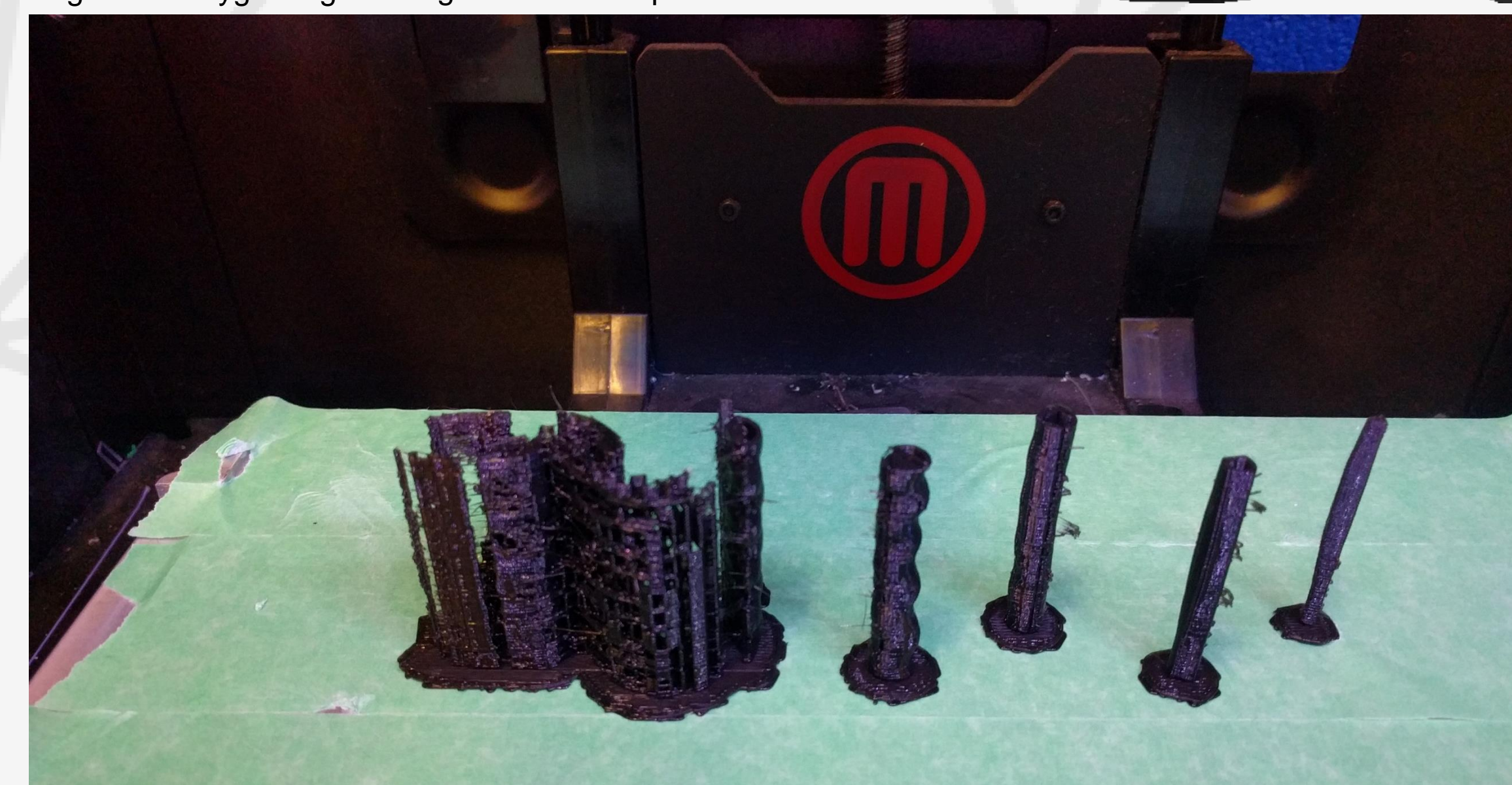


Figure 6. Three-dimensional printed model of flow past a square cylinder exhibiting vortex shedding

Conclusion

This research has determined an optimal procedure to view virtual complex flow simulation as three-dimensional representations in reality. Ultimately using data acquired from CFD software and processing it via the use of ParaView, SolidWorks and MakerBot we are able to formulate three-dimensional printed models of fluid flow. The results from this research will provide an enhanced understanding of the flow to students and serve as educational tools for in-class learning.

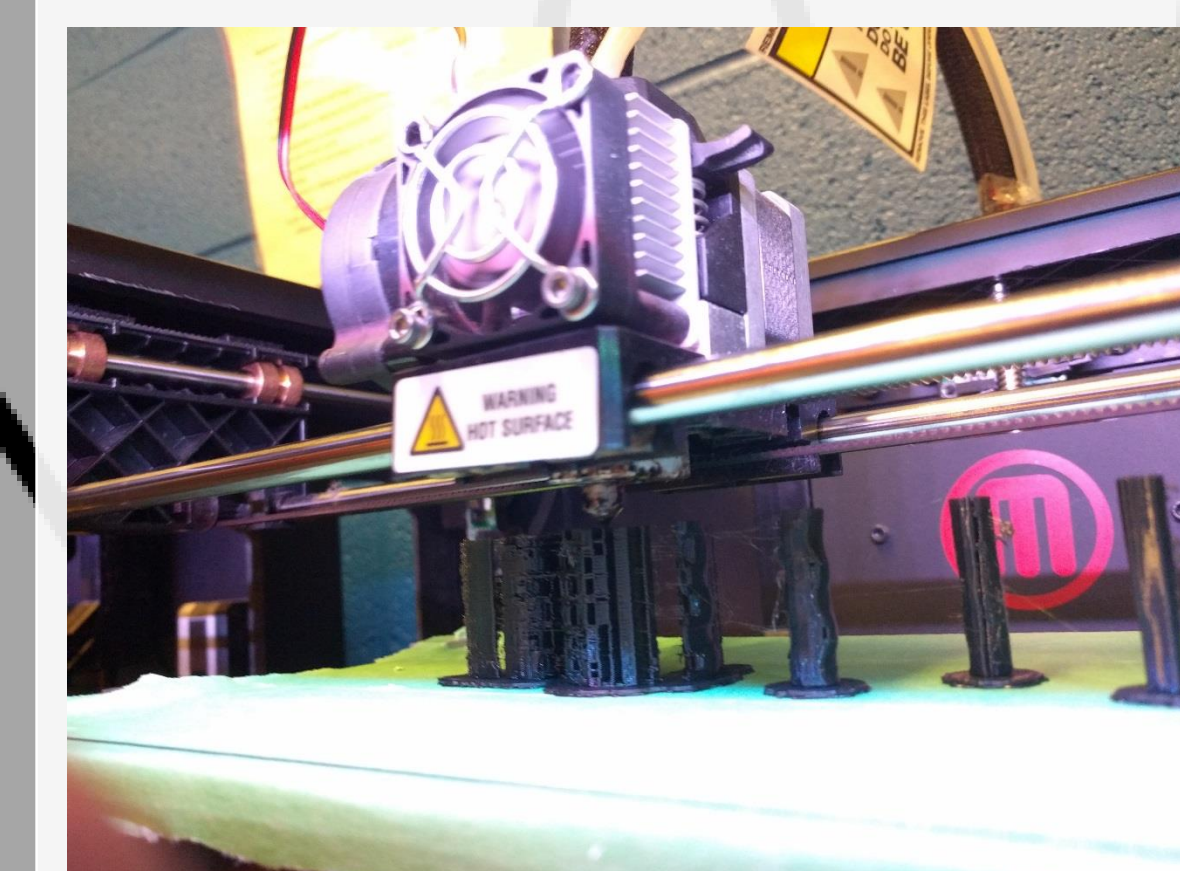


Figure 7. 3D printer in motion using PLA filament

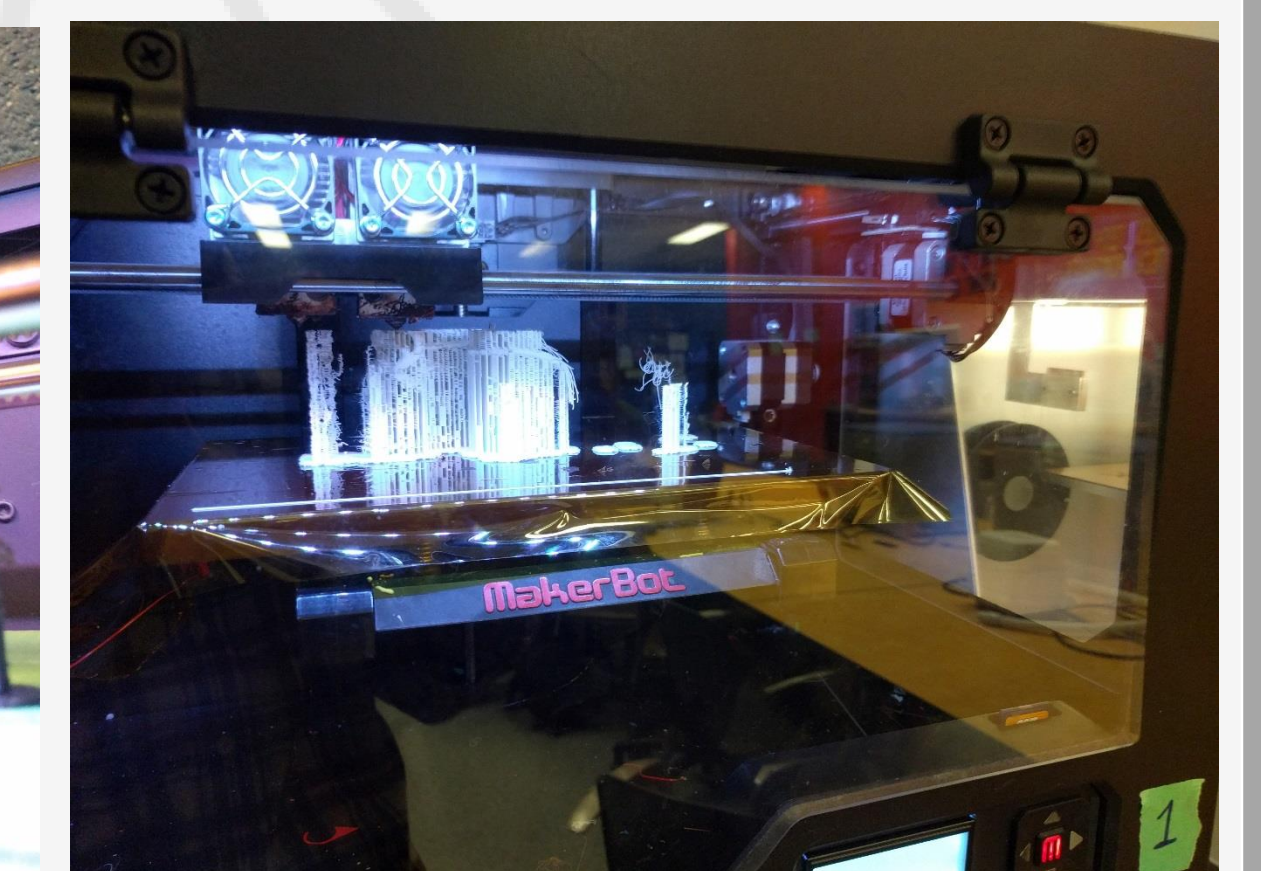


Figure 8. 3D printer in motion using ABS filament

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