Design and Construction of K-9 Learning Tools

Christopher Le Cheminant, Cole Ellis, John Rauch, Mingxuan Li

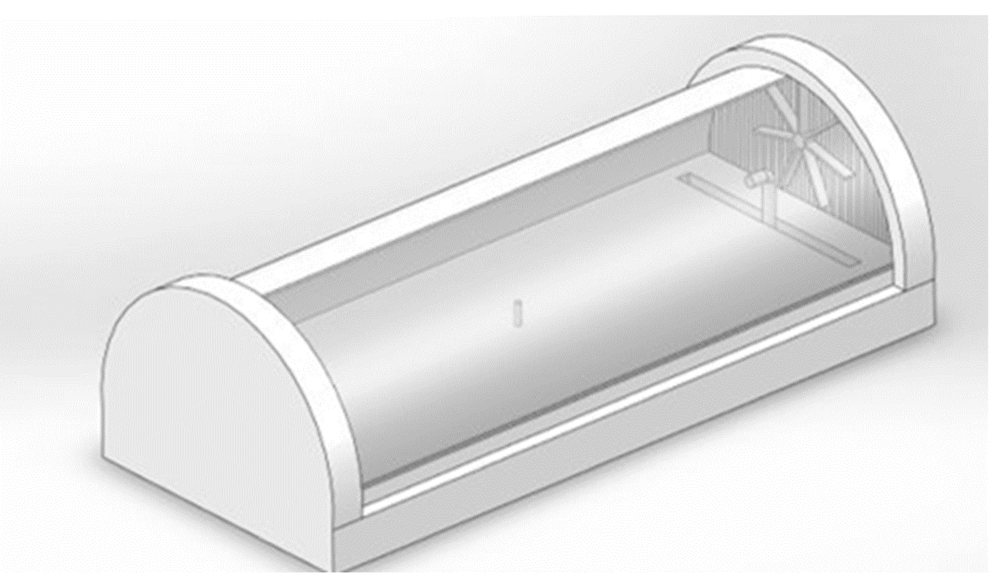
Proposed Problem

Minds in Motion is a program associated with University of Calgary Active Learning, that seeks to inspire youth to pursue passions and careers in the fields of Science, Technology, Engineering and Mathematics through summer camps and in classroom demonstrations.

The aim of the project was to design and construct an exciting and inspiring Mechanical Engineering related activity or demonstration to provide Grade K to 9 students with an experience of the key curriculum concepts that are taught in the classroom.

To narrow the scope of the project, our team decided to target students in Grades 7 through 9. We examined the Alberta Science Curriculum to identify topics that overlap with Mechanical Engineering concepts. The relevant topics are Heat and Temperature; Structures and Forces; Mix and Flow of Matter; Mechanical Systems; and Space Exploration.

Our Solution



Through consultations with Minds in Motion, our team decided to construct an open-circuit, demonstration wind tunnel. We felt this would be an exciting demonstration with diverse appeal while covering several curriculum topics.

Students will compete against one another to assemble modular cars from prebuilt parts. Their goal is to maximize downforce and minimize drag.

This project was preferred by Minds in Motion because it is easily adapted to many other workshops. In the future, students could be able to test airplanes or even their favourite superheroes. It can also be used for their current workshop that teaches about wind turbines.

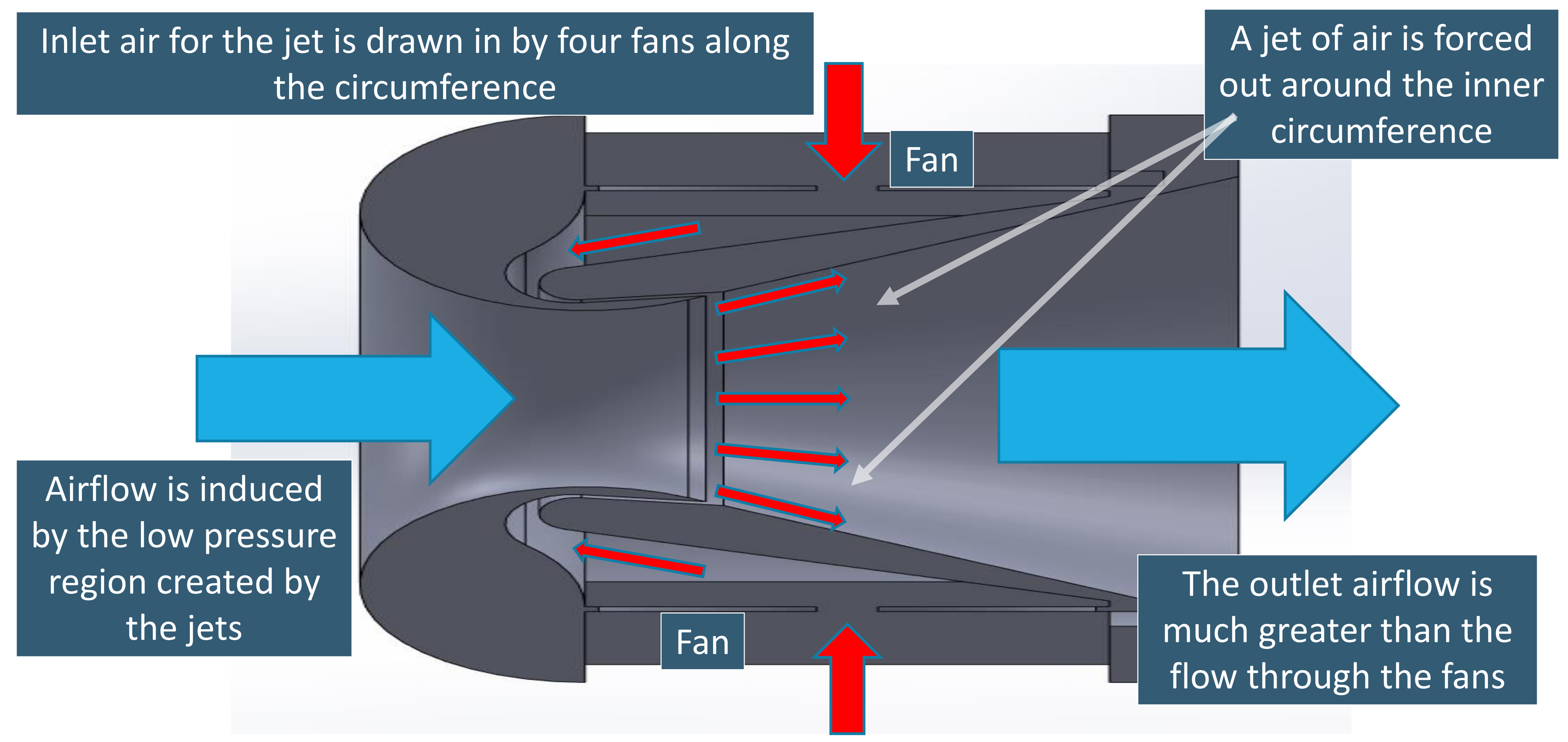
Design Constraints

Minds in Motion provided very few requirements of our possible designs. Primarily, the design needs to be transportable to classrooms by one person, and the workshop should be easy to run without extensive training. Our team decided to add additional requirements of the project.

- Quite enough to operate inside of a school
- Safety measures to prevent contact with and injury from the fan
- Windspeed of 10 m/s
- Method to measure windspeed
- Method to measure lift and drag
- Display for measurements
- Control system to collect data and drive the display
- Method to visualize the airflow such as smoke

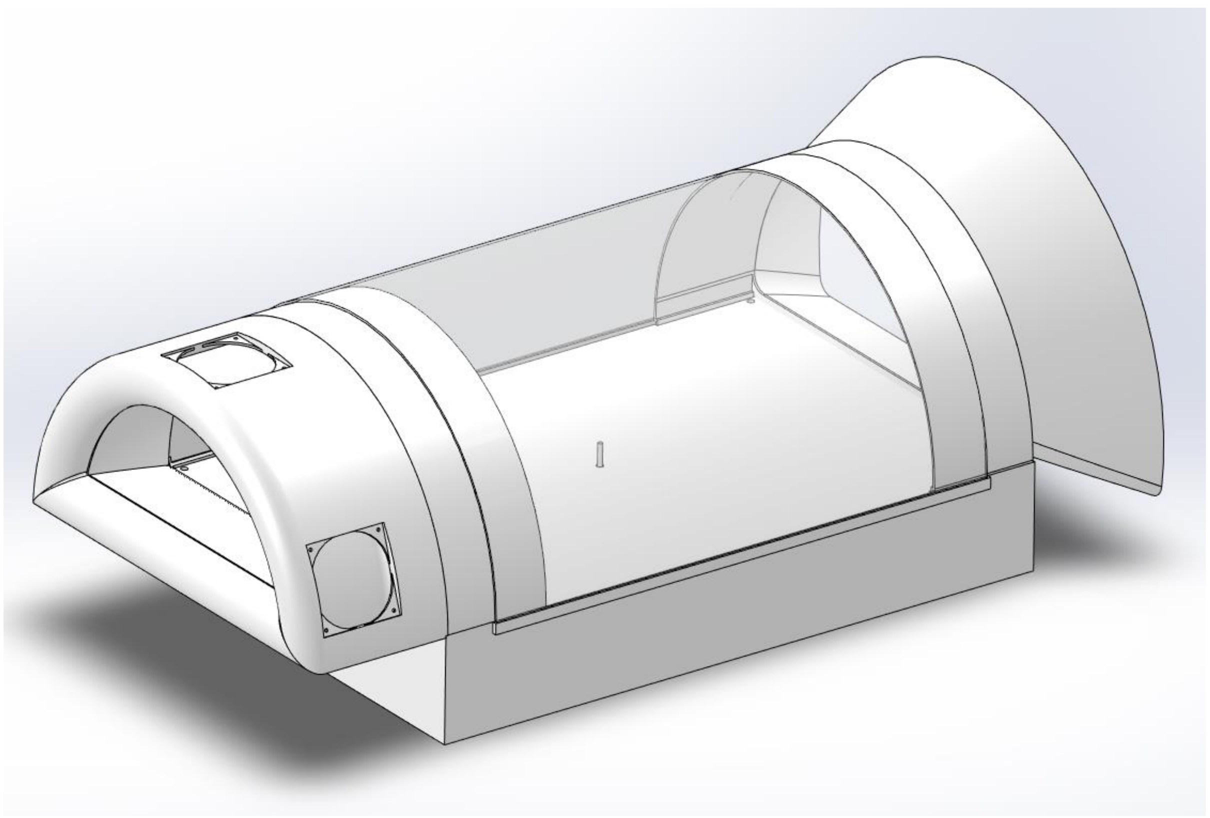
Bladeless Inlet

Due to safety and noise concerns, our team decided to make the tunnel inlet function similar to commercial bladeless fans. These designs typically use a small fan in the base to draw a much greater airflow through the assembly. This happens due to the Coanda effect, which causes a low-pressure region on the inner surface. Our design modifies this concept to use four PC fans around the circumference of the inlet. This allows us to use much smaller fans than would be needed to produce the desired airflow. Studies have shown that these bladeless designs create a uniform, low turbulence flow that is desirable for wind tunnel testing. It has the added benefits of much quitter operation and safer operation because these fans are not powerful enough to cause a serious injury.



Construction

It was decided that 3D printing would be utilized as much as possible in construction. Initially, the team thought the base of the tunnel could be 3D printed, but the decision was made to construct it from plywood to increase the structural integrity. In the end, the inlet and outlet, the car models, the pitot tube, and the test fixture were 3D printed. All the electronic components are located safely in the base.



Electronics and Display

The brain of this project is the Raspberry Pi. It takes input from each of the sensors; the load cells measure lift and drag respectively, and the pressure sensors measure static and total pressure to determine flow velocity.

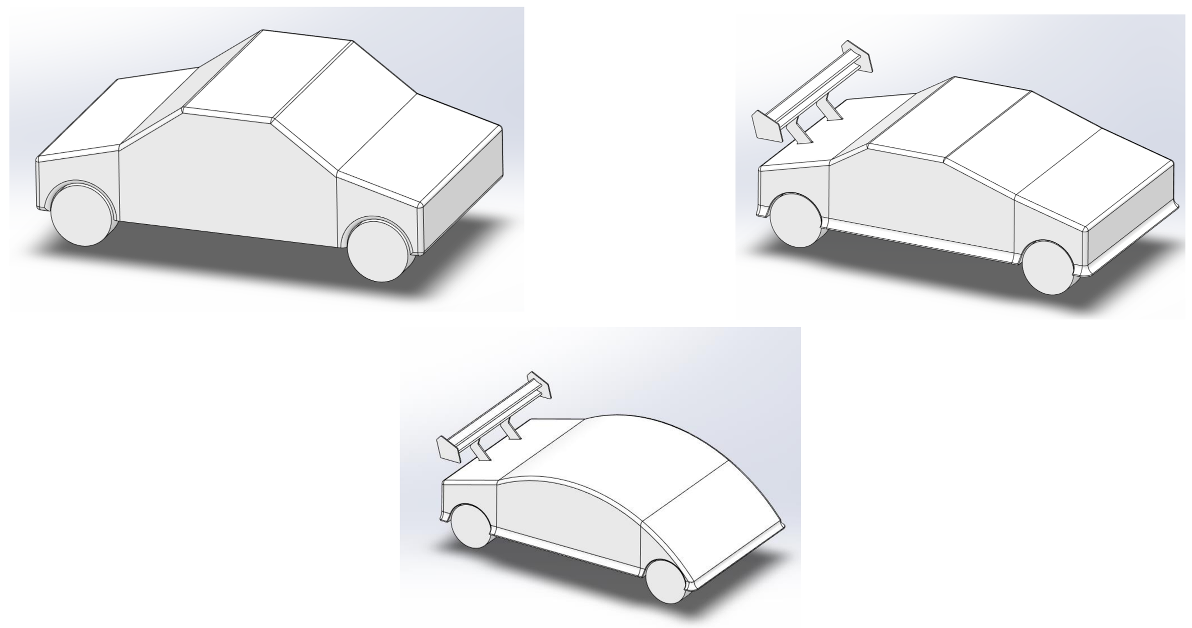
The Raspberry Pi has two HDMI outputs capable of driving a display or projector. A custom user interface was designed using Python to log and display the results of each test. The Pi is also capable of adjusting the fan speed using Pulse Width Modulation.

Electronic Components

- 1 x Raspberry Pi 4 Model B
- 2 x Load Cell and Hx711 Load Cell Amplifier
- 2 x BMP 180 Ambient Pressure Sensor
- 4 x 12V PC fan with PWM control
- 1 x 12V, 84-Watt DC Power Supply
- 1 x 5V Buck Converter

Test Models

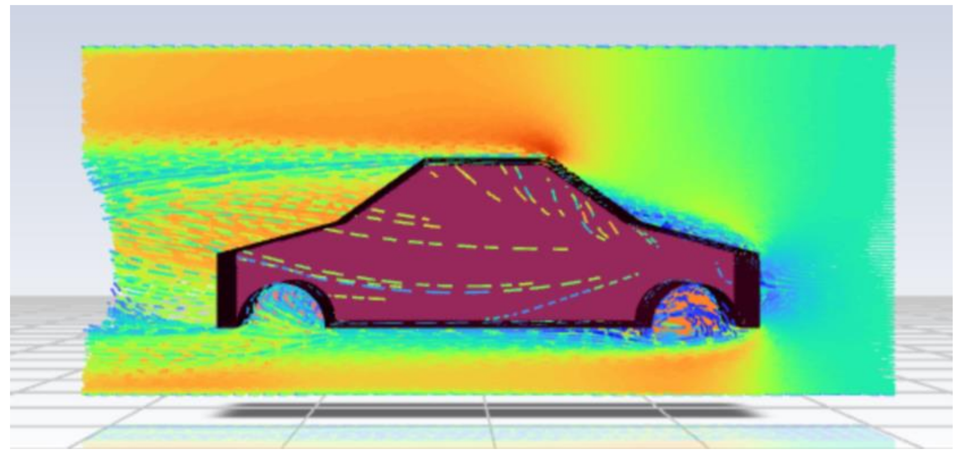
Students can assemble their cars with parts from four categories. Our team has designed three possible noses, bodies, and tails; and students will be able to add or remove the wing from the tail.



Computation Fluid Dynamics

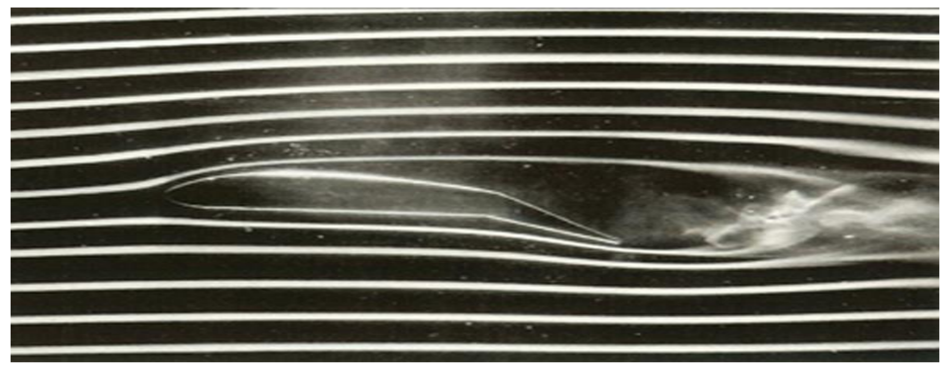
CFD was performed on several combinations of the test models so that the team could the range needed for the lift and drag sensors. Simulations were run in ANSYS Fluent, using a symmetry condition to improve solution time.

During these simulations, it was discovered that the large size of the models caused a backflow in the wake of the models. This would mean that any smoke released in front of the cars would poorly capture the wake, so the models were scaled down and simulations were run again. A special thanks to Dr. Ahmed Bayram for his help with these simulations.



Flow Visualization

Our team felt that flow visualization was a key component to help students understand aerodynamics. Several methods were considered, including olive oil injection, a Halloween fog machine, and attaching pieces of cotton to the surface of the test objects. In the end, it was decided to use dry ice to produce a fog effect, as Minds in Motion has easy access to dry ice through the university.



Acknowledgements

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