Design and Implementation of an Air Multiplier Fan for PC

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Design and Implementation of an Air Multiplier Fan for PC

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Honors Research Project

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Design and Implementation of an Air Multiplier Fan for PC

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Background and Inspiration

I have worked with computers since my sophomore year of high school when I enrolled in a paid technical work experience course that provided great exposure. Since then, I have had a personal interest in computer hardware and applications.

When it came time to select a senior design project, I wanted to find something that interested me, applied what had been covered throughout my degree, and remained somewhat novel. I’d decided to try and scale down an air multiplier fan, more commonly popularized as a bladeless fan by Dyson, and use it as a PC cooling solution. Browsing online/doing some preliminary background work before proposing this topic, I’d found rumblings on enthusiast forums asking whether this had been done. To my knowledge, there had not been a prior application of an air multiplier as a computer cooling solution.

While this is likely due to not being cost competitive with the amount of material required, price is not the only consideration. A product like this could fill a novelty-based niche. Additionally, successful completion of this project serves as a proof-of-concept.
Design Process

Research and Theory

The design process began with researching the most prominent air multiplier designs, Dyson’s. I had little trouble finding information about their designs, with a sizable portion of it being self-published within marketing videos or adverts.

Their “bladeless fan” design most commonly includes dual impellers/fans within the base of the design, with the base also being ventilated allowing it to act as an air intake. Air is then channeled through a shell before flowing through a slim slit and over an airfoil-like inner rim.
With the elliptical-shaped stream of air flowing, there is now a clear pressure difference between the air being forced through the fan and the static air surrounding it (both within the ellipse and outside of it). Referencing Bernoulli’s principle (that increased fluid velocity results in decreased pressure), it is evident that the air flowing is lower pressure than the air surrounding it. Unconnectedly, fluid flows from higher pressure to lower pressure, and in this case, is responsible for pulling in more air.

3D Modeling and Design Constraints

I’d decided to use a PC industry standard 140mm 1200 rpm fan as the driver/impeller housed in the base for my project. This was to expedite the design process/keep it realistic for the tools I had accessible to me. The impeller was not the focus of this project, and would have taken a sizeable commitment to make in and of itself.

The 3D modeling was done within SolidWorks. Design constraints included the size of the computer chassis the air multiplier was to be housed in, feasibility for 3D printing, and a socket for the fan/impeller to slip in. Limitations of 3D printing services offered by the university included maximum dimensions of 25.2 x 19.9 x 15.0 cm, meaning that this design had to be broken up into several components. 3D printed parts with long, wide features like those called for by this design require a wall thickness of at least 4 mm to minimize error and decrease likelihood of breakage. This is thicker than I would have liked, and when combined with the large size of the model itself meant very long printing times.

Snap features connected the base/fan housing to the lower portion of the air foil. The air foil’s top and lower portions were equipped with 4.5mm holes that would use M4 bolts and nuts
to join them to the airfoil walls.

The impeller housing required ventilation to allow air flow in (as well as a slot for the fan’s power header to slip through). Additionally, 4 holes were included in the base that corresponded with holes on the chassis for mounting. An exploded view of the completed assembly (along with a model of a generic 140mm fan borrowed from GrabCAD user Ewashbrook) is viewable on the next page.
3D Printed Prototype

3D Printing

Using SolidWorks, the models I created had to be exported as .STL files, the default/industry standard for 3D printing. Once this was done, I’d submitted them to the University of Akron’s provided 3D printing service for academic prints. The printing service employs a MakerBot Replicator 5th Generation 3D printer, along with a common polylactic acid (more commonly known as PLA) plastic filament.

In general, PLA’s weaknesses are a low melting point (180°C, and a glass transition temperature of roughly 65°C) as well as a low material strength, neither of which are a huge concern in this application. While it is common for a computer CPU to reach 70°C, ambient temperature within the chassis should not approach this value. The above considered, PLA is a suitable material on paper for the design.

The largest drawback of 3D printed PLA is that the MakerBot Replicator uses fused deposition modeling (FDM), a technology that creates the print by extruding heated plastic layer by layer. As a result of the nature of this method of 3D printing, the print ends up requiring quite a bit of support material that must be removed after. This design (and its hollow structures) results in an annoying amount of interior support material that is a hassle to remove.

A more suitable 3D printing method would be selective laser sintering (SLS), which uses a laser to heat material and bind it together layer by layer to create a 3D print. SLS requires no support material, which would have been very appealing in the context of this project. Unfortunately, SLS printers are quite expensive. I submitted my design to Staples’ 3D Services, and the automated price estimate was cost-prohibitive (for a safe/cautious infill percentage of 50%, it was upwards of $200).
Post-Processing

As mentioned above, there did turn out to be quite a bit of support material. The below figure has two red boxes showing a support base and support column, and a thick red line appears next to where there is support material within a fold (it is not easily visible as it is in the interior). The support material within the fold proved quite difficult to remove, and although I was able to remove the majority of it, some small bits remained stuck after post-processing.

Tools I used during post-processing included a simple blade/pocket knife, snips and a basic file. Pocket knife and snips were used to remove support material. The file was used to remove
some material surrounding the snap fits, as the 3D printed prototype exceeded my model’s tolerances and the snap fits would not catch as intended.

**Assembly**

I ran into several problems during assembly as a result of some combination of short-sighted design and the MakerBot Replicator’s inaccuracy.

The first of which, as noted above, was that the snap features did not work properly before being filed down. While greater tolerances within my design could have prevented this, had the prototype then turned out to be smaller than specified rather than larger, then the snap fit may have been too loose. In this case, the assembly would not have been properly mated. The current design would be unlikely to have this issue if it were injection molded, as typical tolerances for injection molded parts is 0.1 mm to 0.25 mm. For reference, the tolerance for the snap fits within my design was 0.5 mm.

The second main issue I faced was that the print was far from perfect. The individual walls of the air foil did not line up at all, despite the geometries in the models being identical. This was very disadvantageous in the context of this project in particular as it relies on airflow. I did my best to join the gaps using cardstock and tape to keep the structure air tight.

The final complication was purely a design issue/lack of due diligence with respect to design-for-assembly. While the component’s adjoining holes left space for the bolts and nuts, there was not adequate space to fit a socket. This, coupled with the general poorly paired surfaces above made the assembly quite a pain.

Despite the above, I was able to get the prototype assembled and mostly functioning as intended.
**Testing Apparatus, Tools and Procedure**

**Apparatus**

I sought to test my design’s cooling ability against a fan that was identical to the one driving it. The chassis used was a modified NZXT Manta that I’d removed some structures from to provide an open environment. Since it is commonplace for computer components to now come pre-equipped with their own temperature sensors, data collection did not require any hardware outside of the computer itself. The CPU used was an Intel Pentium g3258 which dissipates a maximum of 53 W of heat.

In order to minimize the effect of other cooling solutions, Intel’s stock CPU cooler was replaced with a Dynatron Y506 aluminum heatsink. In both testing scenarios, only one identical fan (a 140 mm NZXT fan) was used within the entire chassis, so the only source of cooling outside of the heatsink’s radiation was the convection resultant of the fan being tested.

Testing was conducted in my apartment, which is low humidity and kept as close to 70°F (21.1°C) as my landlord’s thermostat can promise.

**Tools**

To maximize the CPU’s thermal load, a freeware stress-testing software, Prime95, was used. Prime95 stresses the CPU by having it repeatedly compute fast Fourier transforms (FFTs). The sensor data was monitored and tabulated by another free software called HWiNFO.

Excel was used initially to open and grab the data, as HWiNFO outputs a .CSV file type. MATLAB was used to graphically represent and compare the datasets.
Procedure

For the first data set, I tested the traditional 140 mm fan/the control. Once the fan was installed, I turned the computer on and prepared both the Prime95 and HWiNFO softwares. From there, Prime95 was set to poll data on time and CPU, motherboard, solid state drive (SSD) in °C every 1000 ms.

With these preferences set, I began testing with Prime95 set to the small FFT method, which is intended to maximize thermal loads. Once the test began, I began logging data with HWiNFO. I monitored the system throughout the test, and once the temperature had clearly plateaued I stopped the test and saved the log. This took roughly 15 minutes (900 seconds, 900 data points).

Before the next trial, powered off the system and allowed any remaining electricity to dissipate before uninstalling the first fan and installing my prototype. I then turned the computer back on and opened both of the programs used for testing and waited for the temperature of the system to settle again. Once it had settled, I repeated the above steps and saved the data.

When the testing was complete, my first step was to export the data to Excel. Once there, I had to finagle with the time as HWiNFO logs the time of day instead of the time since the start of the log. For example, if I was doing the test in the afternoon, the time column values were all in the range of 12:30:00.0 PM to 12:50:00.0 PM. Excel was used to convert these values to seconds, as shown below. The formula shown is applied to cell B2 and then propagated throughout the remainder of the column. After this, I shuffled the data over to MATLAB for plotting.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Time</td>
</tr>
<tr>
<td>2</td>
<td>12:38:42 AM</td>
</tr>
<tr>
<td>3</td>
<td>12:38:43 AM</td>
</tr>
<tr>
<td>4</td>
<td>12:38:44 AM</td>
</tr>
<tr>
<td>5</td>
<td>12:38:45 AM</td>
</tr>
<tr>
<td>6</td>
<td>12:38:46 AM</td>
</tr>
<tr>
<td>7</td>
<td>12:38:47 AM</td>
</tr>
</tbody>
</table>

=HOUR(A2-SAS2)*3600+MINUTE(A2-SAS2)*60+SECOND(A2-SAS2)
Discussion of Results

The above chart shows that the prototype with 140 mm fan was more effective at cooling the CPU than the same 140 mm fan on its own, with a final settling point ~5°C lower. It should be noted, that in neither situation did the CPU begin to throttle itself due to thermal load. This means that both of the fans were satisfactory when paired with the heatsink, and that even under maximum load the CPU’s thermal dissipation was properly addressed.

The temperature of both the SSD and motherboard did not vary in either scenario, with the temperature of the SSD actually remaining between 40°C and 41°C for the entirety of both trials. Plots are within the appendix.
Conclusions

Complications

As addressed in the 3D Printed Prototype section, there were several issues with the product. A few of these were in my design and are easily addressed. The others were in the FDM process itself and would be more difficult to solve without having to individually correct the issues if I were to print another model.

Concluding Remarks

During the course of this project I was able to apply quite a few skills and concepts that I’d learned during my B.S.M.E. The design utilized CAD modeling software in SolidWorks and basic MATLAB scripting for the plots. Processes taught in my Design of Mechanical Components, Concepts of Design, and ME Lab courses were also directly applicable to determining design constraints and feasibility as well as providing exposure to the 3D printing process. An understanding of concepts such as Bernoulli’s Principle, which is the center of this design, as well as convective heat transfer were critical to this project and also picked up during my coursework.

Once assembled, testing the design was relatively straightforward. The lengthiest part was selecting for or open-source softwares that did what I was looking for. The testing results indicated that the design worked to at least some extent, visibly providing an improvement over the base fan. I am satisfied and consider this a success, although I would have preferred to have had less errors within my prototype. Additionally, I would have liked to implement the system into a computational fluid dynamics (CFD) program if I’d had more experience/confidence with CFD.
References

Appendix

MATLAB Plots

Air Multiplier Prototype vs Traditional 140mm Fan CPU Temps (°C)

![Graph showing comparison between Air Multiplier Prototype and Traditional 140mm Fan CPU Temps](image)

Air Multiplier Prototype T (°C), Traditional 140mm Fan Motherboard T (°C)

![Graph showing comparison between Air Multiplier Prototype and Traditional 140mm Fan Motherboard Temps](image)
SolidWorks Models
3D Printed Prototype