Final Report

Noise Reduction of Roomba 670

AeroVac dust bin

ME4320 - Advanced Engineering Design

Submitted by:

David Strom

Dstrom@wpi.edu

Submitted to:

Professor Joe Stabile

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1.0 Introduction

1.1 Objective

The objective of this project was to analyze the iRobot Roomba 670 AeroVac dust bin and improve the design to reduce noise and vibrations while running. Our team's focus was on redesigning the blower mechanism to allow the motor to run at lower speeds without compromising on suction power. Furthermore, general soundproofing and vibration reduction tactics were explored to reduce overall noise production.

1.2 System Description

The Roomba 670 AeroVac bin is a compact dust collector that provides suction power as well as storage for dust and dirt collected. The suction is produced by a brushed DC motor powered blower system (Figure 1 and 2) which is housed within the dust bin. The aerovac bin includes a latch mechanism to allow for easy insertion and removal. This mechanism also includes 2 metal contacts to supply power to the motor.

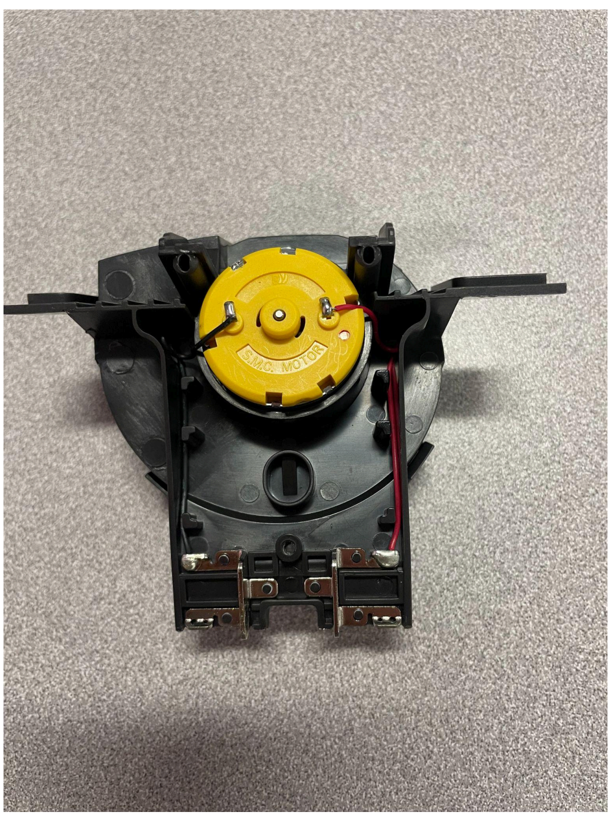


Figure 1(Left): Underside of blower mechanism

Figure 2(Right): Top view of blower mechanism without cover

1.3 Problem Statement

The problem given by iRobot was to find a way to reduce the emitted noise level of the Roomba 670, though our group focused on the AeroVac bin specifically. Ideally, all of the functions of the AeroVac should remain and our solution shouldnt compromise on suction power.

1.4 Assessment of Needs

Req ID	Priority	Type of Requirement	Requirement
1.1	1	Functional	Safety is top priority and so the design of the AeroVac bin must be safe for the end user. Some safety features include but are not limited to: 1. No moving parts (Blower Mechanism) that are exposed when running and powered on. 2. No exposed wiring that could be touched by the end user 3. No sharp corners or other design shapes that could cause injury.
1.2	2	Functional	The redesigned AeroVac must have equal or greater suction power to the original design.
1.3	3	Functional	Air must still pass through the filter before entering the blower mechanism.
1.4	4	Functional	The AeroVac bin must produce less harsh noise or a lower volume of noise in general
2.1	5	Size and Weight	The internal volume of the redesigned AeroVac chamber must be similar to that of the original AeroVac as the amount of debris that can be held in the vacuum should be

			the same.
2.2	6	Size and Weight	The weight of the redesigned component must not greatly exceed that of the original design as making the assembly too heavy could cause complications with the robot's movement.

Table 1: Table of design requirements

1.5 Design Goals

The design goals for the Aerovac dustbin are as follows:

1. Create a vacuum through the Roomba to allow dust, hair, and dirt to be pulled through the vacuum input
2. Filter out impurities in the air and keep them in the collection space while expelling air out the back.
3. Store and allow impurities to be easily removed and cleared when the bin is full.
4. Complete this while the noise remains quieter than the original design.

2.0 Background

2.1 Customer Description

IRobot offers a variety of products to end consumers, ranging from $199.99 to almost $2000. The main customer base of iRobot are tech-savvy homeowners, families, and busy professionals seeking a time-saving solution to household cleaning.

2.2 Use Environment

This updated design of the AeroVac dust bin will be used in a real Roomba 670 for testing purposes. This will allow measurements of airflow, sound, and vibration.

2.3 Design Specs and Constraints

The Design needs to be small enough to fit within the roomba in its preallocated slot. The device also needs to have an internal volume equal to the non-redesigned AeroVac.

3.0 Procedure

3.1 Mind Map and Potential Ideas

Original brainstorming, as seen in the mind map in figure 3, shows our groups original ideas for reducing the noise in a Roomba 670 AeroVac Dust collection bin. Our original theory was to change the number of fins and the blade shape in order to increase efficiency. This would allow the motor to run at a slower RPM and achieve the same suction power. As our initial testing revealed that the motor was the loudest part of the mechanism, running it slower would significantly reduce noise.

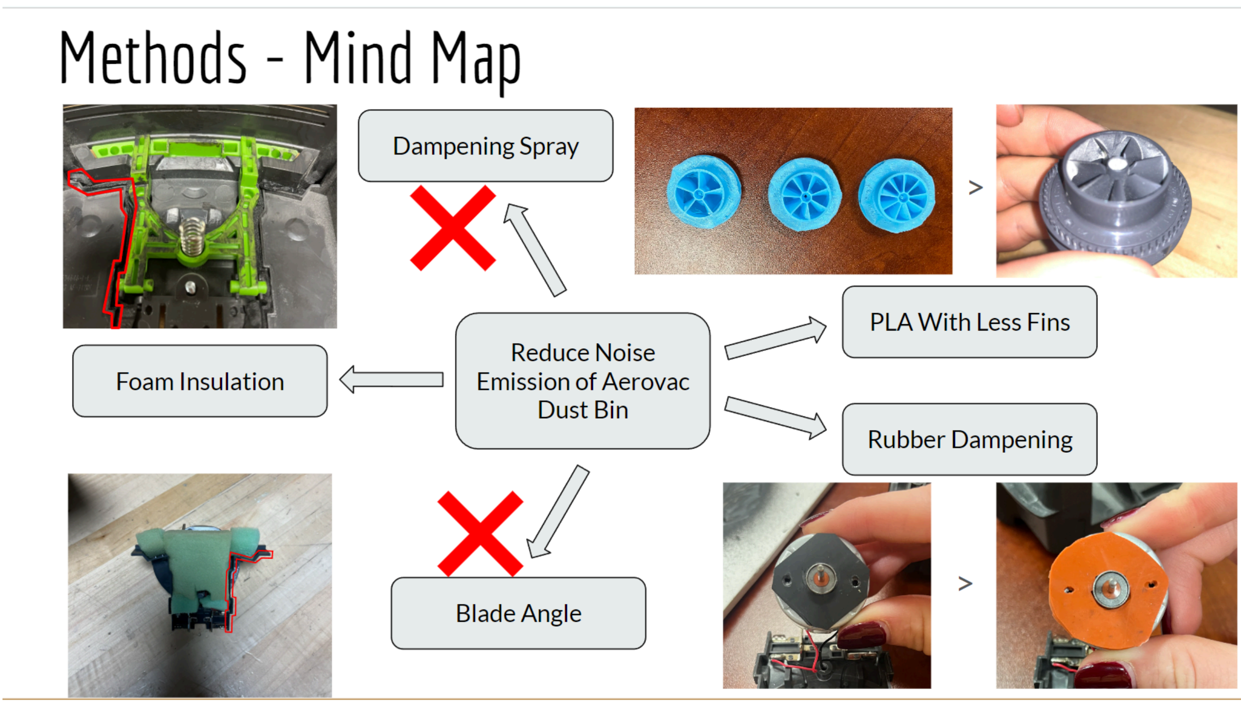


Figure 3: Our teams updated mindmap with what worked(no X) and what didn't(X)

3.2 Fan Redesign

First, we reconstructed the original turbine in Solidworks seen in figure 4 (Center). Additionally, the same design with more and with less blades is seen to the left and right in figure 4. These turbines were 3D printed with a Bambu printer using PLA filament as seen in figure 5.

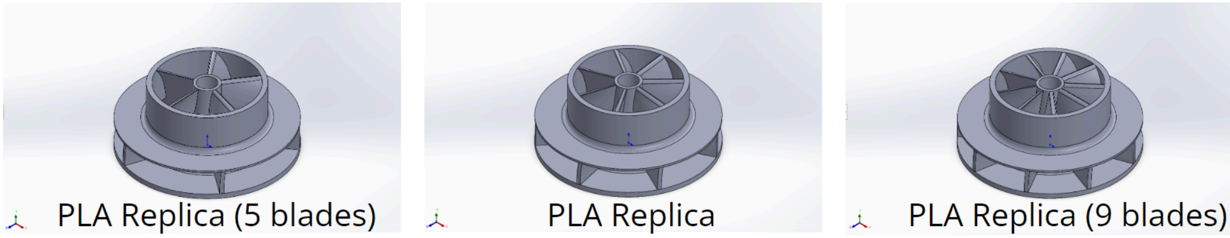


Figure 4: 5 Blade (Left) version of the original turbine, replica of original turbine (Center), 9 Blade version of the original turbine (Right)

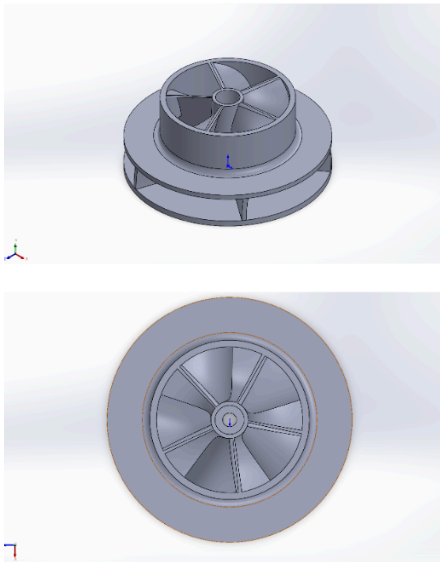
Figure 5: Original turbine (Left), original design made from PLA (Center RIght), 5 blade PLA design (Bottom Right), 9 Blade PLA Design (Top Right)

Our results, as seen in table 2, showed a 1.3 dB reduction in noise from the turbine being made from 3d printed PLA instead of injection molded plastic. Furthermore, the 5 blade design significantly reduced the noise by almost 3 dB. During testing, a piece of paper was used to attempt to measure the change in airflow, but it proved either negligible or unmeasurable with accessible tools.

Assembly	Max (dB)	Min (dB)	Average (dB)
Full Assembly	77.4	74.5	**76.4**
Full Assembly PLA Replica	76.4	59.1	**75.1**
Full Assembly PLA 9 Blades	74.9	72.2	**74.0**
Full Assembly PLA 5 Blades	75.0	63.8	**73.5**

Table 2: Results from DecibleX showing max, min, and average dB of different turbine designs.

The next step was to change blade shapes. It was our hope that by decreasing blade angle, a stronger suction and more airflow would be created. Iterating on our previous design, a 5 blade turbine with decreasing blade angles was created and tested as seen in figures 6 and 7. Unfortunately, this test proved louder and it had a negligible impact on airflow, so this design was scrapped.



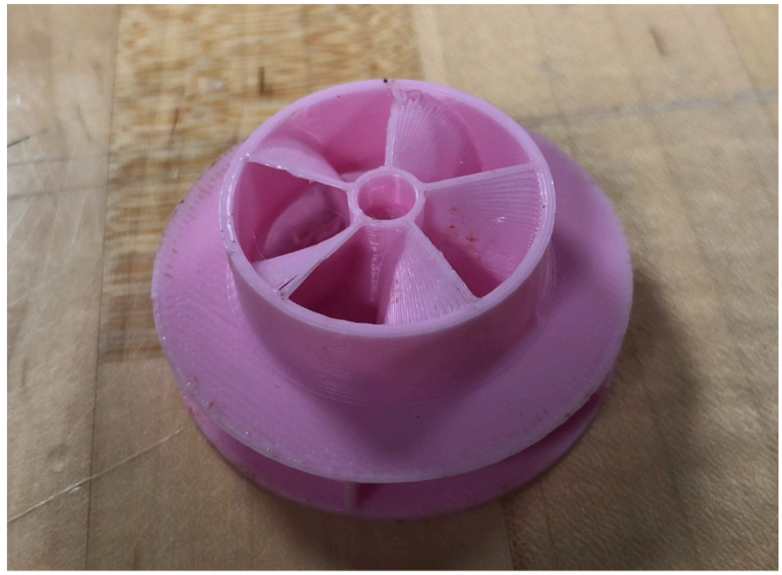
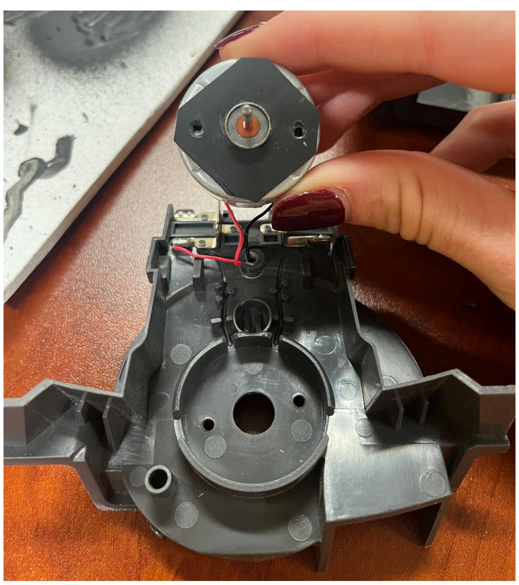


Figure 6:(Left) CAD models of 5 blade design with a smaller blade angle

Figure 7:(Right) 3D printed version of the design in figure 6

3.2 Rubber Dampening

As the motor proved to be the noisiest part, we believed that putting rubber padding to dampen the motor vibrations could reduce noise. To do this, 2 thickness of rubber were placed between the motor and where it was mounted as seen in figures 8 and 9.



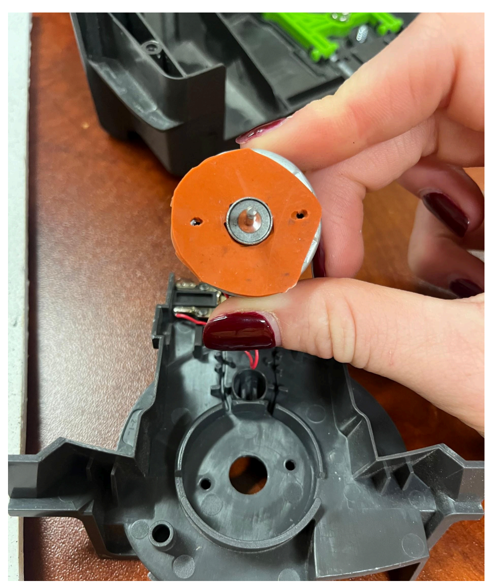


Figure 8:(Left) Thick Rubber

Figure 9:(Right) Thin Rubber

After gathering our results as seen in table 3, it can be shown that the thick rubber reduced the noise by a further 1.1 dB. Interestingly, the thin rubber actually proved much louder, almost completely overwriting the noise reduction of the PLA 5 blade turbine.

Assembly	Max (dB)	Min (dB)	Average (dB)
Full Assembly	77.4	74.5	76.4
Full Assembly 5 Blades	75.0	63.8	**73.5**
Full Assembly PLA 5 Blades w/ Thick Rubber Attached to Motor	73.0	70.3	**72.4**
Full Assembly PLA 5 Blades w/ Thin Rubber	77.1	75.1	76.1

Table 3: Max, Min, and Average dB of the turbine running with thick rubber, thin rubber, and no rubber between the motor and mounting point

3.3 Foam Insulation

Finally, foam was added to voids within the assembly as well as between contact points in order to reduce overall vibration in the whole assembly. As seen in figure 10, there is a void between the outside housing and the motor that was filled with foam. Additionally, as seen in figure 11, foam was added to where the blower assembly and the housing connect (Seen in Red). As seen in table 4, the addition of foam further reduced the noise by another .9 dB.

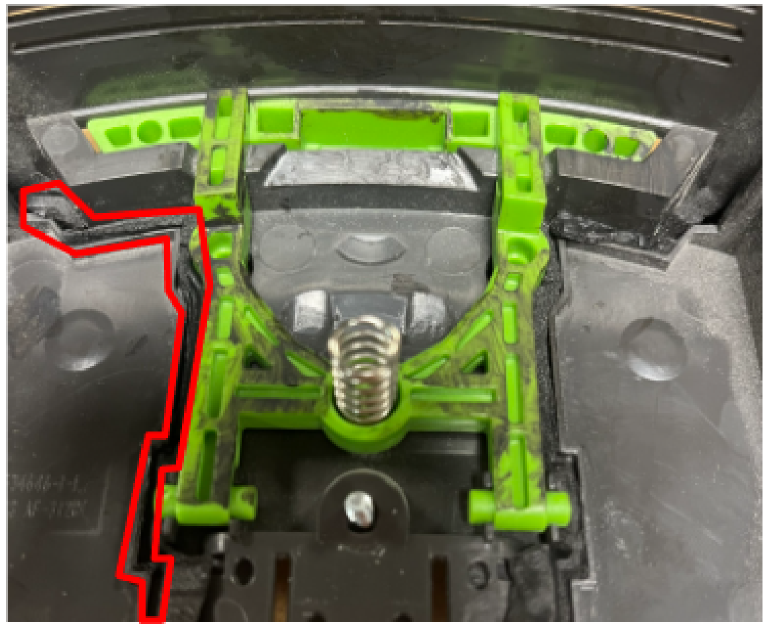
 

Figure 10:(Left) Foam Cut to fit around motor and in void.
Figure 11:(Right) Foam added to inside of housing where blower (figure 10, Top) and the housing (Figure 10, Bottom) connect (Highlighted in Red)

Assembly	Max (dB)	Min (dB)	Average (dB)
Full Assembly	77.4	74.5	76.4
Full Assembly 5 Blades	75.0	63.8	73.5
Full Assembly PLA 5 Blades w/ Thick Rubber Attached to Motor	73.0	70.3	**72.4**
Full Assembly PLA 5 Blades w/ Thick Rubber & Foam	72.9	70.8	**71.5**

Table 4: Table with new results from adding foam

3.4 Manufacturing Process

Our manufacturing process, as seen in figure 12, is a quite simple prototyping design loop. After acquiring materials, the parts are assembled and tested. Then, from our results, conclusions are made and new designs are presented. Repeating this eventually allowed us to come to a final design.

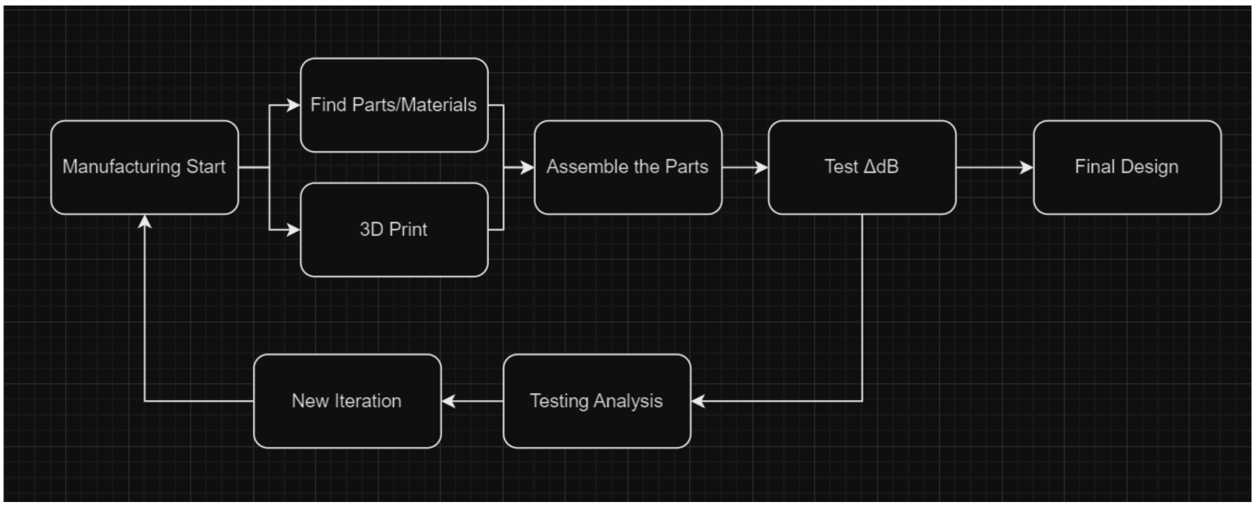


Figure 12: Flow Chart of Manufacturing Process

3.5 Final Design Conclusions

3.5.1 Strengths

1. Noise Reduction: A total of 4.9 dB reduction in noise was produced
2. Suction Power Maintenance: The change in suction power and airflow proved negligible
3. Material Optimization: The use of PLA 3D printing for turbine prototypes allowed for rapid testing and quick iterations
4. Vibration Control: The thick rubber dampeners and foam inserts reduced motor vibrations
5. Ease of Manufacturing: The design maintains simplicity, enabling a cheap and effective way of implementing into the manufacturing process

3.5.2 Weaknesses

1. Fragility of 3D Printed Components: While the 3D-printed PLA turbines offered noise reduction benefits, they may not be as durable as injection-molded components in long-term use. Furthermore, imperfections are more common with 3D printed turbines

2. Inconsistent Airflow Measurements: Due to limited access to precise measuring tools, changes in airflow caused by turbine blade modifications were difficult to quantify.
3. Added Weight from Dampening Materials: Though light, the addition of foam and rubber do increase the overall weight of the Roomba

3.5.3 Additional Changes Made Based on Problems Encountered:

Several additional changes were made during the prototyping process to address problems encountered:

1. Switch to 5-Blade Turbine: The initial design, which featured different blade counts and angles, was iterated upon based on noise testing results. The 5-blade design, which ran at a lower RPM, provided a better balance between noise reduction and airflow.
2. Thicker Rubber for Vibration Dampening: Early tests with thin rubber between the motor and its mounting point resulted in increased noise. The design was revised to use thicker rubber, which significantly improved vibration dampening and noise reduction.
3. Foam Insulation in Critical Voids: During testing, it became apparent that certain areas within the assembly were prone to excess vibration. Foam was added to fill voids between the motor housing and the blower assembly to address this issue, resulting in further noise reduction.

4.0 Conclusions

4.0.1 Was the problem solved?

Overall, a reduction in noise was produced. The redesign of the AeroVac dust bin for the Roomba 670 successfully reduced overall noise without compromising on suction power or airflow. The combination of the redesigned turbine, the addition of foam, and the addition of rubber dampening all resulted in a quieter assembly.

4.0.2 Were the goals met?

Yes, the design goals were met as the final assembly was quieter without compromising ojn performance.

4.0.3 Will users' needs be satisfied?

As the operating volume of the Roomba is of utmost importance, any reduction, even ~5 dB, will satisfy users and result in a more appealing product.

4.1 Recommendations

4.1.1 Go/No Go?

The assembly is almost a go. I would recommend doing airflow and suction testing before this addition is added to mass production.

4.1.2 Future Work

For future work, several improvements are recommended to further optimize the AeroVac dustbin design:

1. Enhance Material Durability: 3D Printing is often expensive and more complicated over that of injection molding. So, further research into easier manufacturing methods for the turbine that do not require a 3D printer or for it to be made from PLA.

2. Refine Airflow Measurement Techniques: Use more precise tools to measure airflow changes from different turbine designs and ensure optimal suction power.
3. Reduce Component Weight: Explore using lighter foam or rubber materials to reduce the overall weight of the assembly without compromising on vibration dampening.
4. Long-Term Durability Testing: Only small scale tests on durability were completed. Additional stress testing could be beneficial.

5.0 Bibliography

5.1 References

IRobot®: Robot Vacuums and mops. iRobot®: Robot Vacuums and Mops. (n.d.). https://www.irobot.com/

5.2 Additional Acknowledgements

Professor Stabile

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iRobot

Innovation Studio Staff