Operation Manual

Team 6

Applying Noise-Reduction Techniques to a Handheld Centrifugal Hair Dryer

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ABSTRACT

The purpose of creating an operation manual for a handheld, centrifugal hair dryer is to ensure that the user has sufficient knowledge in order to safely and enjoyably operate this device. The contents of this report also contains the device's functionality, along with a schematic of the original device and its additional sound-reducing components. The user will also be shown the process in which the device was assembled, and how to troubleshoot potential issues that may occur during the handling or operation of said hair dryer. Keep in mind though, the overall goal of this project was not to completely design a quieter hair dryer; the group decided to carefully determine the main noise contributing factors of multiple hair dryers, then apply sound-reducing engineering techniques to a chosen hair dryer at multiple noise-causing sources of that device.

1. Introduction

Hairdryers are commonly found throughout the world, most notably in one’s own household bathroom. Their popularity and development has grown over the 20th century due to the inherent nature of its main function: which is to dry hair! Since its birth, several additional features had been applied to thousands of the hair dryer designs, such as variable speed switches, cold-air buttons and even nozzle attachments for styling. One less common feature that can’t be found in the majority of hair dryers is a function which reduces the noise output of hairdryers.

The operation of any hair dryer is synonymous with loud noise. There is an increasing demand for hair dryers to have built-in sound-reducing capability, however, the unfortunate tradeoff for such a function is cost; multiple added features’ drives the overall cost of an albeit simple device from $20, upwards to about $250 for a premium hairdryer with seemingly endless amount of functions. However, these so-called premium hairdryer’s focal point usually resides about enhancing the overall appearance a person has after use, and not about their ability to hear after drying their own hair. This rising problem is something this group has decided to tackle; by applying multiple engineering techniques, the group has developed a way to achieve great hair, while saving the user’s ability to clearly hear after drying their hair.

2. Functional Analysis

2.1 Project Function

The function of this project is driven by the scope of the project, which is to identify the primary source of noise within a centrifugal type of handheld hairdryer, then make repeatable and measurable noise reduction improvements through modifications via design aspects, while maintaining its overall flow performance. After several months of work which revolved about this scope, the group has reached and exceeded several milestones; reading several research papers about reducing sound, running several experiments to locate primary and secondary noise contributing factors, designing models by the assistance of computer-aided drafting software, developing actual physical parts via 3-dimensional printing technology, and performing tests to better improve their final design were some of the major goals reached throughout the months. Sufficed to say, the group has developed a product. As mentioned before, the scope of the project is to make sound-reducing improvements to a centrifugal type of handheld hairdryer, which is quite different than making a brand-new hairdryer from “scratch.” Without further delay, the group redesigned the fan blade system within a chosen centrifugal type of hairdryer. As simple as this may seem, the methods the group used to make such design can be applied to any centrifugal type of hairdryer’s fan blade system.

2.2 How Does Redesigning a Fan Blade System Work?

One may ask themselves, “how does this process work?” Several answers can be provided to respond to such a bold, yet logical question. As the motor’s shaft rotates the fan blade system within a centrifugal type of hairdryer, naturally the fan rotates as well. What most people do not realize is there is a specific type of frequency associated with this action; this is referred to as the *blade pass frequency*, or BPF. This BPF of a fan is defined as the number of revolutions the fan makes per second, multiplied with the number of blades of the fan [1]. Generally, humans can hear frequencies within the range of 20 to 20,000 Hz, but are most sensitive within the range of 1 to 2 kHz. The blade pass frequency determined from the group’s observed hairdryer, operating on the high speed switch, was approximately 444 Hz. Fortunately, this value doesn’t reside within the range of sensitivity, however, cheaply designed or axial-styled fans approach (if not reside within) this sensitivity range; this ultimately has a huge impact on the user's hearing after prolonged usage. While the BPF does not fall in the 1 – 2 kHz range, its harmonics do. These are integer multiples of the BPF that appear in the signal that can sometimes even be stronger than the lone BPF.

Without electrically adjusting the actual rotational speed of the motor, the group devised several ideas in order to redesign the fan blade system. One of which is to reduce the *quantity* of blades used within the fan system. Mathematically speaking, just reducing at least one blade within the system reduces the overall blade pass frequency, however, keep in mind that removing too many blades will degrade the volumetric flow performance; ultimately, excessive blade removal makes a hairdryer ineffective with respect to drying one's hair. So cautiously removing a modest number of blades can reduce the overall sound pressure level as will be explained below. The image below (Figure 1) shows the frequency spectrum calculated from the chosen hairdryer measured in both A-weighted and Non-A-weighted scales. This spectrum is generated by taking a Fourier Transform of the recorded noise signal that breaks down the contribution of each distinct frequency to the overall noise level. The overall sound pressure level is determined based on the area underneath the curve. The A-weighted scale is used to mimic human hearing, as it dampens the lower and higher frequencies where human hearing is less sensitive. The BPF in both scales appear at approximately 312 Hz. To take advantage of the A-weighting our goal is to move the noise to lower frequencies where they will be at a frequency less harsh to human hearing. By applying a reduction to the number of blades on the fan it would shift the BPF lower. This allows for the BPF and its harmonics to appear at lower frequencies and thus reducing the perceived sound level.

A complementary idea with blade removal is to reduce the amount of blades within the system to a prime number. Naturally with blade pass frequencies are associated harmonics following the BPF. By using a fan blade system with, say perhaps 29 fan blades (29 is a prime number), breaks the periodicity of the noise signal. Because this number cannot be evenly divided into one revolution (360˚) of the motor and fan it has an effect on the noise spectrum that diminished distinct tones and spreads them out over a larger range of frequencies. This has an overall effect on the annoyance factor that is associated with the BPF and its harmonics.

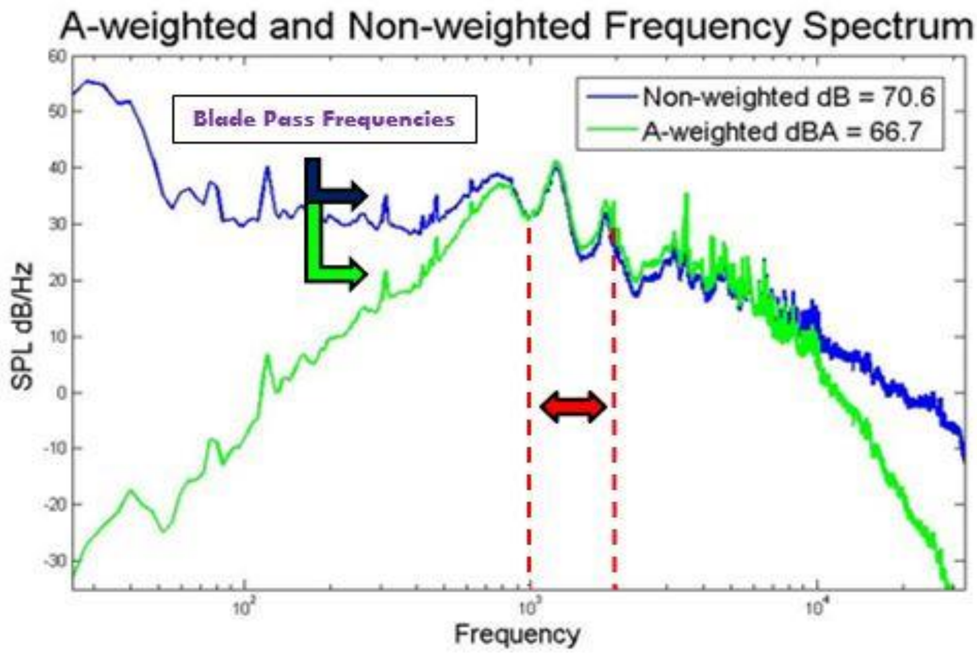

Figure 1: "A" and "Non" Weighted Frequency Spectrum of Hairdryer from 0.02-20 kHz

Other fan designs have been created along with that of reducing the number of blades, and their performance and noise characteristics are intended to be tested. Increasing the blade area, both where there was a reduction in blade number and no reduction, will allow for improved flow rate as surface area increases. This will be one way to compensate for the loss of flow rate in decreasing the number of blades. Both increasing and decreasing the diameter of the fan, as to change the distance of the fan rotation and the tongue of the housing where a majority of the noise is created. For smaller diameters, this would diminish the impact of the packet of air leaving the blade as it comes into contact with the housing. Also, adding trailing edge serrations to the fan blades would passively break up the packets of air leaving the fan blades sooner and diminish their impact on the housing.

A chevron nozzle tip was also designed in order to apply noise reduction to the flow leaving the hair dryer. It is a 3D printed component that passively induces mixing of the exiting flow by adding serrations to the outer edge of the nozzle. This diminishes the resulting shear layer formed from interaction between the created jet and the quiescent air. The larger scale vortices that are created from in the shear layer are a source of noise and reducing these would allow for a noise reduction.

3. Product Specifications

3.1 Fan Blade System

The group replicated the original fan blade system as well as a model that has 29 blades. The idea behind replicating the original fan blade that came with the hairdryer was to determine how closely the 3D printed versions would mimic the noise of original fan. In order to have this as an effective means of prototyping our fans, we would need the noise output of the 3D printed replica to be very close to that of the originals. One with 29 blades was also printed to have a comparison between two 3D printed blades. The creation of the rest of possible fan designs were delayed until it could be determined that this prototyping method was sufficient. Some key features of the fan blades and main dimensional focal points to observe in the fan blade system are the upper and lower diameters, blade size, and mounting hole areas. The values for these and other specifications can be located in the table in Appendix A (Table 1).

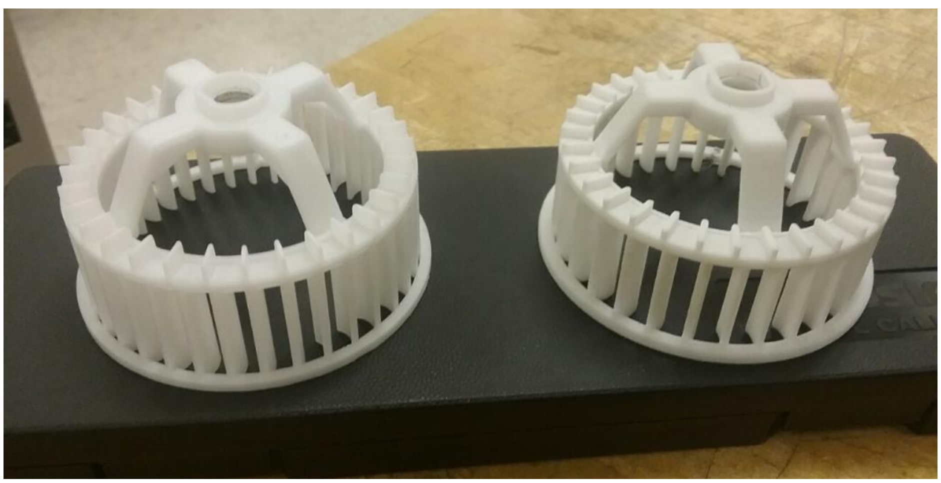

Figure 2: Original (Left) and Replicated (Right) Fan Blade Systems

The method of 3D printing was selective laser sintering (SLS). This method breaks the CAD file into 0.1 mm thick horizontal slices of the model. The part is printed from the bottom up by using a laser to melt a nylon powder in the places of each layer of the CAD model. The print generated tight tolerances and a slightly rougher surface compared to the original. Upon testing the fan, it is determined that there is significant vibrations that are associated with the unbalance of the part. This was a risk that was known when pursuing this method of prototyping, but was still the only reasonable means that our fan modifications could be created quickly and within the budget. Another method of prototyping could have included injection molding, but are generally saved for mass production runs and still do not offer guaranteed balance on the first iteration. Work is being done to dynamically balance the centrifugal force that is causing the vibrations. This is done by applying weights around the fan to cancel out the force vector that needs to be balanced.

3.2 Chevron Nozzle

The chevron nozzle is another product the group created for this project. It partially alleviates unwanted noise at the nozzle’s exit by simplifying the mixing transition of the differed air velocities of the jet and the stationary air. The product contains 5 saw tooth-like edges, and the apparatus easily fits over the end of the nozzle’s exit in a snug manner. An image of this product can be seen below (Figure 3) and further information regarding its measurements may be found in Appendix-A (Table 2).

Figure 3: Chevron nozzle tip

4. Operation and Maintenance Instructions

4.1 Fan Removal/Installation

After purchasing the hairdryer and removing it from the box, the initial step is to rest the item on a flat surface (do not plug in hairdryer until process it complete). Next, acquire a small list of tools, such as a small Philips head screwdriver and a 0.5” flathead screwdriver. Once acquired, use the Philips head screwdriver to remove a few screws from the outer casing in order to slide the nozzle off of it, along with one half of the hairdryer’s outer shell; a transitional set of images of this process can be seen below (Figure 4).

Figure 4: Stages of hairdryer casing removal

Next, use the flathead screwdriver to remove the fan from the shaft of the motor. To do so, maintain firm control of the fan with one hand, and rotate the flat headed slot to the left in order to loosen the nut; the nut maintains contact between the motor shaft and the fan. The phases of this process can be seen ahead (Figure 5).

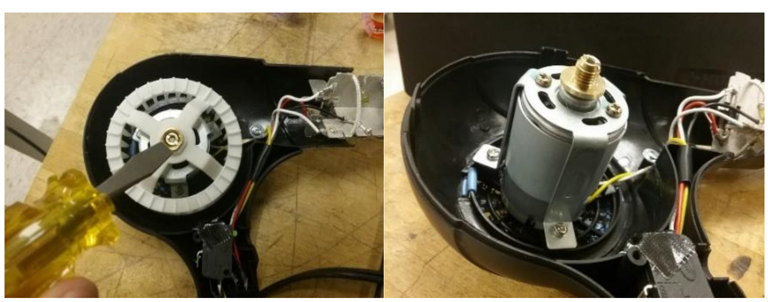

Figure 5: Stages of fan removal

Once the motor is exposed, take the modified fan blade system and follow the previous steps in reverse order. The final step is to include the chevron nozzle, which can be seen ahead.

4.2 Chevron Nozzle Installation

After the fan is installed and the housing is securely fastened, it is time to install the chevron nozzle. There are no tools required for this section. All one would have to do is take the chevron nozzle and insert it over the end of the main nozzle of the hairdryer. This simple process can be seen below (Figure 6).

Figure 6: Images of the hairdryer without and with the chevron nozzle attached

4.3 Operating Instructions

In order to operate the hairdryer, one would simply insert the power plug into a suitable wall outlet; this will allow the user to activate the hairdryer. Once powered the user will be able to activate the variable heat/speed switch and/or the cool shot button; by using these functions allows the user to change the speeds of the hairdryer, along with the temperature output. After use, simply shift the variable heat/speed switch to its initial position; this will turn off the hairdryer. Lastly, remove the hairdryer's power plug from the wall.

4.4 Maintenance and Safety

There is very little maintenance that would need to be performed on the hairdryer during its lifespan. Some minor instances to take heed would be to ensure that the hairdryer's intakes or exit are not blocked during operation; this would eventually overheat the hairdryer, therefore activating the automatic safety shutoff mechanism. If this occurs, carefully unplug the power cord and allow the hairdryer to rest and cool for approximately 15 minutes before attempting to use the hairdryer again. Also, the power plug contains a *ground fault circuit interrupt* (GFCI) in order to protect the user from potential water immersions or overheating.

If one is using the hairdryer, and chooses to test whether the GFCI function is operable, the user should keep the plug in the outlet, press the *TEST* button located on the plug (this should turn off the hairdryer), followed by pressing the *RESET* button (this is also located directly on the plug).

If one suddenly drops the hairdryer into a pool of water, immediately refrain from using the hairdryer. DO NOT ATTEMPT TO GRAB THE HAIRDRYER FROM THE WATER!

In order to reduce the risk of any burns, electrocution, fire, or injury to any user, please take careful note of the following information:

- This hairdryer should never be left unattended while it is plugged into a wall outlet
- Maintain close supervision when the hairdryer is used by, on, or near children
- Only use this appliance for its sole purpose: Drying Hair
- Never use the product if the power cord is damaged; return to manufacturer for servicing
- Ensure cord is not exposed to high temperatures
- Never wrap the cord around the hairdryer after usage
- Never block any openings of the hairdryer during usage
- Do not attempt to place loose objects within hair dryer before, during, or after usage
- Avoid usage when nearby free-floating gases such as aerosols or oxygen are present
- Do not point the hairdryer directly into any person’s eyes or sensitive regions
- Do not operate appliance while it is not firmly in control of the user’s hand/s
- Do not attempt to operate hairdryer with a voltage converter or in an improper wall outlet
- Do not utilize the hairdryer while being connected to an extension cord or surge protector

5. Conclusion

In conclusion to this report, the user should have sufficient knowledge regarding not only the typical operating instructions found within any appliance's packaging, but also some basic engineering information that went into the noise-reduction process. It has included the reasoning behind modifying the fan as well as that of the chevron nozzles and shown how improvements can be made to the original hair dryer to improve sound quality.

References

[1] Nijhof, M., Wijnant, Y., De Boer, A., & Beltman, W. (n.d.). *Reduction of fan noise bymeans of (circular) side-resonators; theory and experiment* (p. 403, Rep.).

Appendix A - Measurements

Table 1: Measurement Values for Specific Parts of the Redesigned Fan Blade System

Aspects of Redesigned Fan Blade System	Measurement Value
Lower Rim Thickness	0.0875”
Lower Rim Diameter	3.0475”
Upper Rim Thickness	0.1025”
Upper Rim Diameter	2.8525”
Inner Mounting Hole Diameter	0.3140”
Depth to Inner Mounting Hole Entry Point	0.1085”
Inner Mounting Hole Depth	0.1185”
Under Mounting Hole Diameter	0.5850”
Under Mounting Hole Depth	0.1215”
Weight	0.7160 oz. (20.3 g)
Quantity of Blades	29
Blade Chord Length	0.2690”
Blade Angle of Attack	> 5˚
Blade Thickness	0.0700”
Blade Height	0.9385”
Material	Fiber Filled Nylon

Table 2: Measurement Values for Specific Parts of the Chevron Nozzle

Aspects of Chevron Nozzle	Measurement Value
Weight	0.3668 oz. (10.4 g)
Overall Height	1.2375”
Max Diameter	1.8925”
Inner Base Diameter	0.3225”
Inner Base Depth to Base of Tips	0.5115”
Height from Tip Base to Top of Tip	0.7385”
Tip-to-Tip Spacing	0.8100”
Base Tip-to-Base Tip Spacing	1.0835”
Tip Thickness	0.1725”
Nozzle Base Thickness	0.0875”
Material	ABS
Coating	Acetone Bath
Inward Tip Curvature	≈ 35˚