Design for Manufacturing, Reliability, and Economics

Team 6

Applying Noise-Reduction Techniques to a Handheld Centrifugal Hair Dryer

Members:

Shawn Eckert	sme13b@my.fsu.edu
Kiet Ho	kth13c@my.fsu.edu
Mark Johnson	maj12b@my.fsu.edu
Peter Van Brussel	pav11b@my.fsu.edu

Faculty Advisor

Dr. Cattafesta

Sponsor

Dr. Devine

Instructors

Dr. Gupta

Dr. Shih

Date Submitted

April 1, 2016

Table of Contents

Table of Figures

Acknowledgements

Dr. Cattafesta has been very helpful towards understanding how to conduct sounds tests and incorporate sound cancelling techniques. He not only allowed the group access to the Anechoic Chamber in the AME building for sound testing, but also gave great feedback to the presentations.

Dr. Devine gave helpful advice to the business concept of the project and how one conducts a marketing/commercialization strategy in order to sell the product in the real world.

Dr. Kumar has been helpful in volume/pressure testing within the Thermo-Lab.

The Class of 2016 students have also been helpful in giving back great feedback of the presentations conducted by Team 6.

ABSTRACT

There is a fundamental problem with the current design of many hair dryers, which is the fact that they produce an unappealing amount of sound during use. This present endeavor will seek to design a hair dryer that is quieter than what is currently on the market while maintaining the same performance of a typical hairdryer and a reasonably low cost of manufacturability. Optimal results of this project will include a working prototype and a business plan for marketing/commercializing the product. In order to reduce the sound production of a hair dryer, Team 6 will target and aim to improve the loudest noise sources that are currently in hair dryers. The significant noise sources are found to be a combination of the fan and its intake, the fan flow over internal components and the motor operation. Many of the project constraints were chosen in order to maintain consistency with the current market for hair dryers.

1. Introduction

Hair dryers are an easily found appliance in countless homes across the country. Currently the average hairdryer produces a sound level that is bothersome, invasive and harmful. Some examples include salons where hair dryers are constantly in use producing excessive noise pollution, or the case where someone is sleeping in close proximity of someone needing to dry their hair. The average hair dryer also produces a sound level that can be threatening to one’s long term hearing with prolonged use. Being that there is this inherent problem associated with the current hair dryer, it offers a niche in the market for this project to fit a need. A solution that would be deemed fit is to be able to offer the same amount of power output, while reducing the noise that it produces compared to current hair dryers in the market. This project also asks the group to analyze the entrepreneurship aspect and to generate a product that is suitable for the current market by creating a device that meets safety regulations, provides equivalent drying quality, and also is quieter. With this in mind, all design aspects must be made to ensure the product can easily be transferred to the market and be mass-produced inexpensively.

2. Design for Manufacturing

2.1 Fan Design and Manufacturing

The fan system of the hair dryer was aimed to be redesigned in order to improve the performance of the hair dryer. It was determined that fan speed is the largest contributor to the overall hairdryer noise, thus improving the flow performance would allow for a reduction in fan speed to produce the same flow rate leading to reduced noise. To redesign improvements to the hairdryer fan system we choose to modify a fan system in a hair dryer that we could have a baseline to compare to. Three types of empirical modifications were devised that would possibly improve fan noise. The first is reducing the number blades on the fan as to reduce the fan the blade passage frequency, hoping this would reduce the noise more than reduce the flow. The blade number reduction would also be aimed to go to a prime number as to break the periodicity of the noise signal. Secondly, increasing the surface area of the fan blades so that flow rate could be improved by using the excess room in the housing. This would be done by increasing the height of the blades. The third modification would add serrations to the trailing edge of the hair dryer as this would diminish the strength of the air packets leaving the fan blades as they impact the walls of the housing. These modifications either aim to reduce the noise produced by the fan or improve its performance, both would lead to improvements in the sound quality of the device.

To manufacture these parts, the group wanted to make, our team turned to additive manufacturing also known as 3D printing. The first iteration was using a FDM type printer where the tolerances are not that tight and surfaces are quite rough. This was mainly a proof of concept that we could 3D print our parts with some level of accuracy. The next iteration was greatly improved as the group looked into a selective laser sintering (SLS) type printer. This breaks the CAD model into 0.1 mm thick horizontal layers and uses a laser to melt powdered nylon plastic layer by layer as it builds the model up. This created very tight tolerances on the part with almost identical replication to the first original. The only difference was the surface finish on the SLS parts were a little rougher.

Two fans were physically manufactured. The first is an exact replica of the original fan in the hair dryer and the second is a modification with fewer fan blades. The purpose of the original replica is to test the validity of this means of prototyping. One main worry with 3D printing was that there was a possibility of unbalance that would be created in when operated on the motor. This unbalance would create heavy vibrations that would create more noise. The weights of the prototypes were 4 grams heavier for the replica and 2 grams heavier for the 29 blade fan. The validity of the prototypes would be tested by both noise and flow rate where the goal is to decrease noise and not decrease flow rate by more than 10%.

3. Design for Reliability

3.1 FMEA Analysis

There are three main situations that could cause the product to fail and by using the industry-standard Failure Modes Effects Analysis procedure, the situations can be described below in tabular format (Figure 1).

Key Process Step or Input	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended	Responsible	Actions Taken
What is the Process Step or Input	In what ways can the Process Step or Input Fail	What is the impact on the Key Output Variables once it fails (Customer or internal requirements)	How Severe is the effect to the customer	What cause the key input to go wrong	How often does cause or FM occur?	What are the existing controls and procedures that prevent either the Cause or the Failure Mode	How well can you detect the Cause of the Failure Mode?		What are the actions for reducing the occurrence of the cause, or improving detection?	Who is Responsible for the recommend action?	Note the actions taken. Include dates of completion
Operation	Short Circuit	Will not dry hair	10	Water damage, faulty circuit interrupt	1	Ground fault circuit interrupt	3	30	Keep Hair dryer away from liquids	Electrical Engineers	N/A
	Motor Burns Out	Will not dry hair	10	Extensive use, voltage spike	3	Ground fault circuit interrupt, AC to DC converter	3	90	Do not run hair dryer for an extensive amount of time. Let motor cool down	Mechanical Engineers	N/A
	Heating Coil Over Heats	Will dry hair much longer	6	Restricted intakes, faulty blade	2	Easily Cleanable intake covers, Removable Intake covers, Bimetallic strip	2	24	Check intakes and make sure they are clean and debris free.	Mechanical Engineers	N/A

Figure 1: Image of FMEA Process Guide

3.2 Fan Testing and Performance

The initial test our fans for was as simple as replacing it in the hair dryer and running it. To mount it only requires a screw and nut that hold the fan into place. Upon first run we could immediately determine that there was an unbalance associated with the prototypes. This resulted in substantial vibrations that produced more noise that was already present. The vibrations were slightly greater for the 36 blade replica than the 29, which could be attributed to the greater mass of the fan and larger imbalance.

The group has worked to both statically and dynamically balance the fans. To statically balance the fans, the group placed it on a spindle where we could determine which side it dipped to and placed weights to level it. This improved it slightly, but the best bet was to dynamically balance it. To do this we purchased a putty and fishing weights to place around the edge of the fan in order to balance the resulting centrifugal force that was causing the vibrations. This method is very much a trial and error and involves placing the weight then running the fan until improvement is determined.

3.3 Hair Dryer Flow Simulations

CAD models were created in SolidWorks that would allow us to perform flow simulations in order to test the fan performances. The only two components of the hair dryer created were the fans and the housing, which usually comes in multiple parts but was created as one for simplicity in the model. The main goal of this modeling was to perform a study to test the fan performance and this does not require intricate details of the model. An exploded view of the fan inside of a demonstrated-version of the chosen hair dryer can be seen ahead (Figure 2).

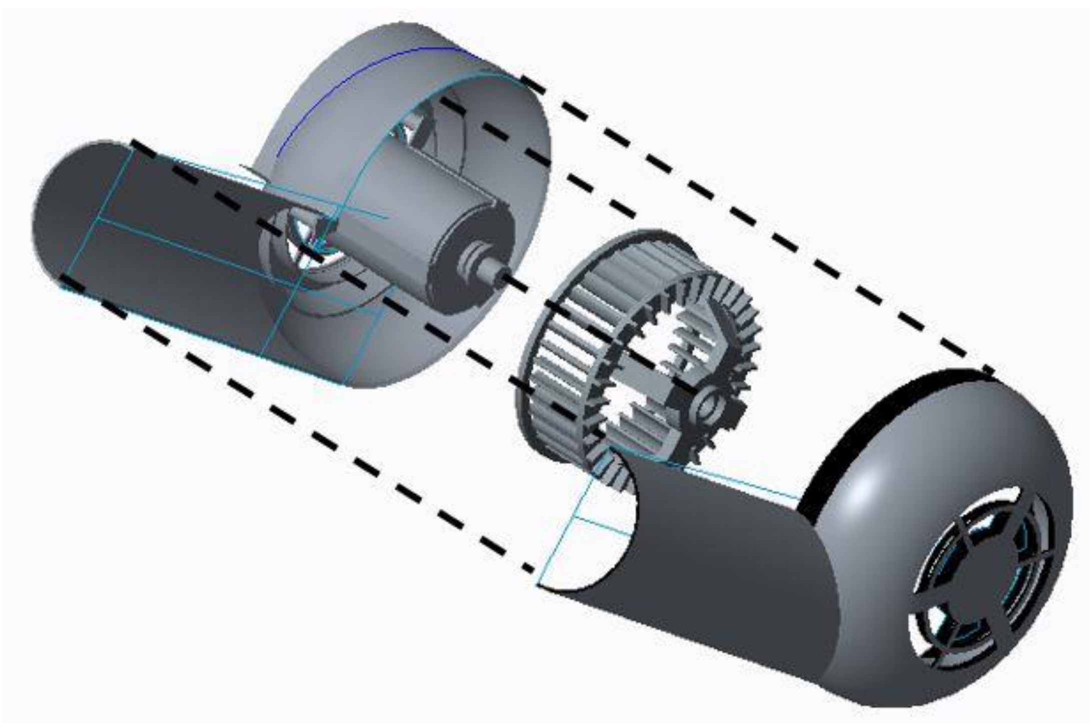

Figure 2: Exploded view of fan in hairdryer

Although the goal of the SolidWorks flow simulations were to test the performance of various fan designs, we were unable to attain quality data from the simulations. The computational requirements needed to perform 3 dimensional simulations of this magnitude were far too great to be run on our computers. The program was unable to resolve the flow between and around the fan for the computational power we had. What it did provide us was flow trajectories for the path of the air flow. These are shown below and gives an idea of how the flow behaves (Figure 3).

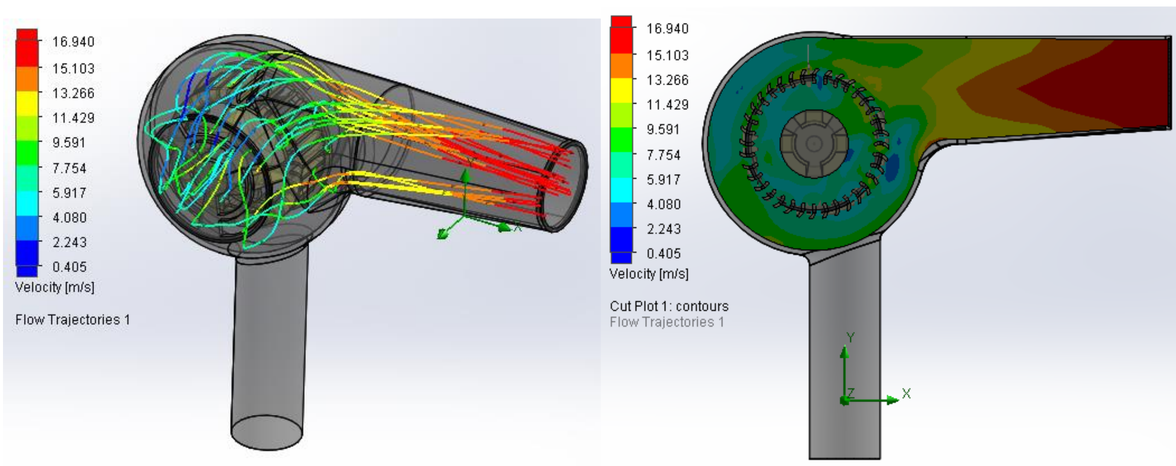

Figure 3: Flow trajectories and contours of velocity

4. Design for Economics

Hair dryers can be very expensive because of the technology they contain; this can result in them running as high as $250. The pricing of the hairdryer depends mostly on the motor, the fan type, and the heater. Most cheap hairdryers use a brushed DC motor and axial fan design. This is because the combination of a cheap motor with a short lifespan and easily configurable fan design makes producing this type of hairdryer easy and cheap. The more expensive hair dryers incorporate an AC motor and centrifugal type fan design which allows the hair dryer to last for a long time and perform very well compared to its cheaper counter parts. However, the AC motor raises the price of the hair dryer by a large amount, roughly $80 more. The centrifugal design also requires a much different set up that is tougher to manufacture compared to the axial type design. Though the price of the hair dryer is raised by a substantial amount the end result is a hair dryer that not only performs well but will last a very long time. Team 6 wanted to combine both of the different type of hair dryers into one so that the user gets the best performance while not spending too much. The design chosen incorporated a higher quality DC motor so that the weight of the hair dryer would not raise by much as well as to keep the price of the hair dryer reasonable. The design also included a centrifugal type fan design for it characteristic of low sound production. Sound production being the center point of this project, a great deal of other sound reducing techniques were incorporated into the design such as chevrons both on the tip of the nozzle and on the trailing edges of the centrifugal fan blade. The design also includes noise cancelling materials such as sound absorbing rubber that is lined within the centrifugal housing and the exterior.

4.1 Competition Comparison

The cost to design and manufacture a fully functional “silent” hair dryer is $193.97 which does not include the research and multiple competitor hair dryers that were used to gain insight on the design of a hairdryer. The figure below shows the breakdown of this year’s project budget of $1,500 (Figure 4). The majority of the budget was spent on researching different ways to quiet a hair dryer and all of this is included in the misc. section. The second largest portion of the budget was spent on 3D printing blades/chevrons, because this was the main source of the noise produced by the hair dryer and targeting it was the biggest priority. This section only includes one fan blade and one chevron.

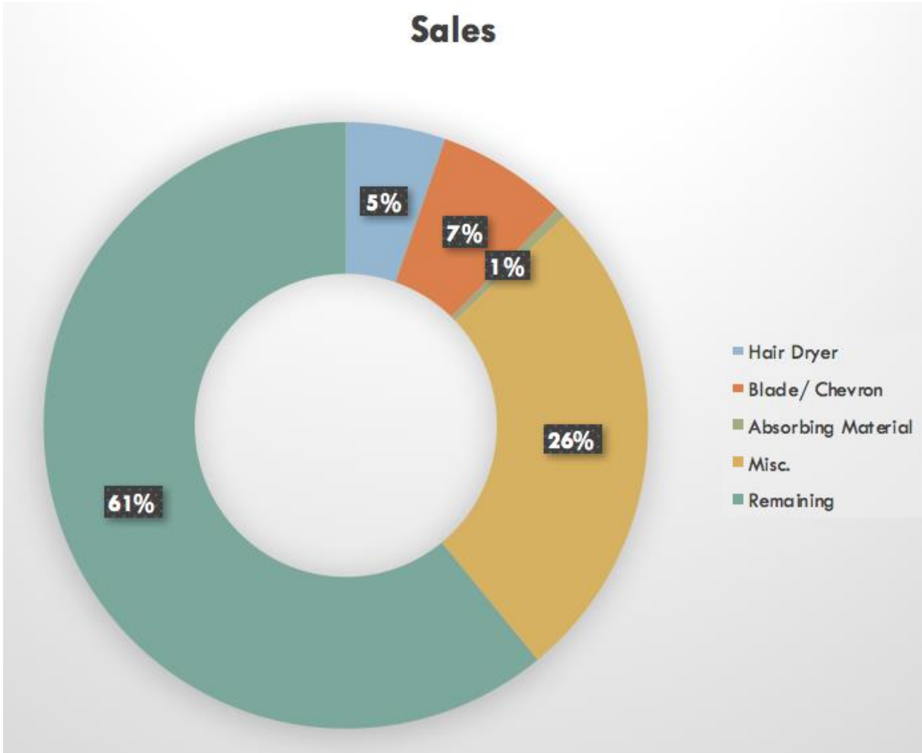

Figure 4: Financial Chart of Budget ($1,500)

The 3D printed blade was done by an SLS printer and the chevron was done by an abs plastic 3D printer. The price of the blade and chevron were $100.03 and $5 respectively. The hair dryer section includes one hair dryer that was completely gutted and used for the final design, this product had a total cost of $80. Absorbing material took up the least amount of the budget and it only includes *plasti-dip* which has sound deadening characteristics, the total cost of it was $8. The remaining budget came out to be 61% of the total budget which will be used to further improve on the design for future designs. Many improvements can be done to the hairdryer while keeping the price lower than $250, these improvements include higher quality blades and motor.

The two most popular quiet hair dryers on the market include the Bio Ionic “Whisper Light” and the Centrix “Q-zone”. Both companies make different hair dryers but the chosen hair dryers are the quietest made by both companies. Both of the purchased hair dryers cost around the same price of $240-$250 and both produce around the same SPL of 71 dB. The figure ahead below shows where team 6’s hair dryer stands compared to the other two by pricing (Figure 5).

Figure 5: Price Comparison of Purchased Hair Dryers Versus Hush Dryer

As one can see, the Hush Dryer is roughly $40 cheaper than the Whisper light hair dryer and $50 cheaper than the Q-Zone which makes the Hush Dryer a very competitive product. With the added benefit that the Hush Dryer is quieter than the other two hair dryers and retains the same performance standards for drying hair.

4.2 Potential Buyers/Market

The Hush Dryers lower cost isn't the only factor that makes it a viable competitor within a market over run with different hair dryers that proclaim to be the best. The quiet performance the Hush Dryer is able to produce makes it desirable for a customer wanting to keep an environment peaceful while drying hair. A prime example of this customer would be professionals working at a hair salon, must professionals would find the quiet hush dryer to not only dry hair effectively but do so in a quiet fashion. This would create a more peaceful environment for the customers getting their hair dried because the customer would be able to speak freely to the professional. A different example would be a professional who grooms pets. As many may know pets are very sensitive to loud sounds and introducing a quiet hair dryer to the market would be very beneficial to the professionals and the pets.

The Hush Dryer can also extend to household use, normal day to day customers will find that a quiet hair dryer attractive because in the morning or late a night when their partner is asleep one could still dry their hair without waking their significant other from a peaceful sleep. The market for hairdryers is also growing within the next few years for all forms of customers which can be seen below (Figure 6). This certain time would be a perfect chance to introduce a new hair dryer to the market without there being too many competitors.

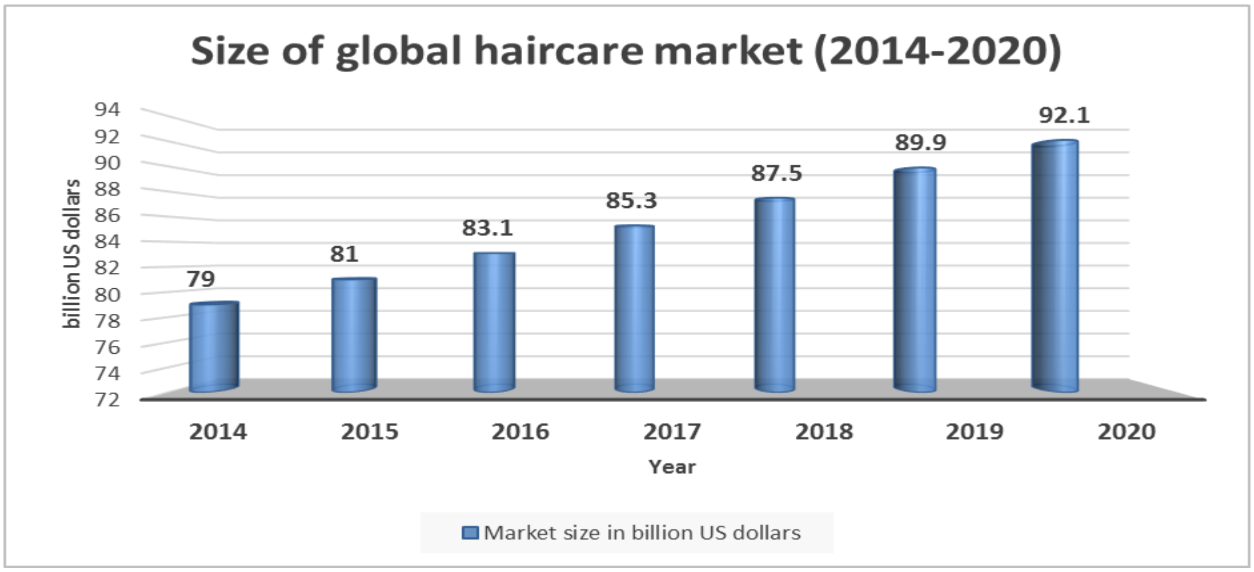

Figure 6: Hair Dryer Market Growth