AC 2010-431: APPLYING DESIGN PROCESS TO REDESIGN A PERSONAL CARE PRODUCT – INTEGRATION OF TECHNICAL AND MARKETING ISSUES

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Applying the Design Process to Redesign a Personal Care Product Integration of Technical and Marketing Issues

Abstract

As part of the curricula in the College of Engineering and Applied Sciences (CEAS), there is a requirement of an Interdisciplinary Senior Design Project for the students to complete during their last year in school. The projects typically are proposed by faculty members based on some particular interest or specific need that they might have, or in collaboration with industry or businesses in the area. Other options are projects proposed by students based on their own interests. The preferred option, from the faculty's and students' perspective, is to have industry-sponsored projects, where students can get exposure to some industry or business and as well as feel the added responsibility of responding to someone other than the faculty and/or staff that they have already interacted with for at least couple of years. Although, at the start of these Interdisciplinary Projects, students leaned more towards working on some internal project, they have come to realize the benefits of having an external project, where more realistic and practical considerations can be seen. Additionally, the competitive nature of most students moves them to select projects that are not trivial endeavors.

In this particular instance, the interesting aspect of this project is that the project was requested – or offered – by a start-up company, which meant that factors other than purely engineering and technical ones needed to be taken into consideration. The product is an electric nail file. The goal was to come out with a new flexible design, together with a justification to prove that the proposed product will be attractive to commercial as well as individual customers. Based on the objective, a complete typical engineering design cycle was utilized. There are electric nail files in the market nowadays so, a survey was conducted in order to identify problems with existing offerings in the market and, at the same time, identify what would be attractive to different market segments. Background information was obtained in order to be aware of the health and safety issues important to the nail care industry. Brainstorming and conceptualization took place, with design, manufacturing/production and business aspects being considered. Computer-based tools were applied for modeling and concept modifications, and virtual prototypes were created, for aesthetic and ergonomic evaluation. In the end, a set of four designs (from entry-level to professional) were proposed, all with a similar core design but different specifications, features and material. Despite the initial teasing endured by the senior group about the type of product being designed, at the end, the sponsor and the students considered the experience worthwhile of an interdisciplinary capstone design project.

Introduction

The engineering design process has different meanings to different people, which sometimes makes it difficult to have adequate design projects for Senior Design capstone activities. But when a project has the potential to involve more than the standard technical activities that engineering students usually understand as being what "design" is all about, the project lends itself to be a great opportunity to illustrate the actual meaning of the complete engineering design process.

At Western Michigan University (WMU) there is the requirement that all CEAS's undergraduate graduating students must complete a Senior Design Project in a two-semester sequence. Projects are presented by faculty members in the College, and students indicate their preferences. Subsequently, teams are formed, with the number of students in each team being decided by the technical advisor(s), the course coordinator, and any sponsor(s) in function of the expectations for the project. Most of the teams have three students, and students' preferences have shifted in the past years from having more interest on internal projects (i.e., no industry involvement) to having projects where an industry sponsor is involved. Among the many benefits and responsibilities that industry sponsored projects provide, one specific benefit is the opportunity to emphasize to the students that engineering design is more than just doing the calculations that were typically done in the classroom.

Faculty members need to search and request projects from their network of industry practitioners. An alternative is to channel occasional requests received by the College from small business and entrepreneurs for technical advice and engineering work. That was the case for this project. A small business had the need for full development of a personal care device, an electric nail filer. The sponsors have been involved in the beauty salon business for several years and now they were looking to expand their presence with such a product. After some initial meetings at the College, and due to financial constraints, it was decided to present the project in the Senior Design class as a concept-to-prototype endeavor. This was a great opportunity to expose the students to a complete engineering design process.

Background

Many of us tend to take for granted our fingernails. However, fingernails speak volumes about our overall health. Problems that arise with the nails can actually indicate problems in other areas of the body. One technique commonly used to take better care of nails is to have them manicured. A standard manicure usually includes filing and shaping of the nails and the application of polish. Filing of the nail is performed using a file or emery board and it can be done on natural or acrylic nails. This filing process is done by hand and has been performed for the past few centuries. Major advancements have been made to the nail filing process within the last few decades. The development of an electric nail file has made filing nails faster and easier for workers in salons. By wielding an electric-powered file effectively, a nail technician can file, fill, and polish acrylic nails in 30 minutes or less.

The salon services market has increased from $5.2 billion in 1995 to $6 billion in 1996[4]. By 2003, the industry has increased to an annual spending of $6.45 billion[8]. The number of employees working as manicurist has also increased in the last ten years. These numbers demonstrate how large the competition is in the manicurist market. In modern days it has become extremely easy for a person to take care of their nails, in part due to the availability of electric nail files. There are many advantages to using an electric nail file instead of using a regular files; one advantage is that the nail technician is capable of performing numerous tasks with an electric nail file[6]. Additionally, electric nail files also have numerous speed controls as well as other accessories for the operator's preference[1]. Sanitation capabilities are provided which offer protection for the client and nail technician. An electric nail file is used for hard-to-reach areas around and under the nail and cuticle areas. The electric file is also used for shaping nails, high-

shine buffing, natural nail prep, and refining tips[5]. Most electric nail files have had the same drill type design since they were first introduced. Some improvements have been made over the years, such as forward and reverse directions, addition of a foot control, portable cordless units, and digital controls with set memory[7]. The human body was not designed to withstand any form of abrasive force, and the nail is no exception. The use of drills must be done very delicately or injuries can occur. Even when a professional does this, there is no guarantee. Drill bits have the tendency to slip whether the user is skilled or not[2]. Fungus forming can also be a downside to drilling. This is caused from excessive deterioration of the nail, preventing the nail from being able to protect itself on a microscopic level[3].

Objective

This project encompasses the development of a redesigned electric nail file intended to be used on human nails, focusing on improving appearance and performance. The existing product has gotten acceptable acceptance, which convinced the owners of a small company to explore the possibilities of an improved design. In this project it is needed to pinpoint problems, missing features and potential areas of improvement in existing devices. Once these items are identified, the basis for the redesign has been established. The project had four goals that were kept in mind throughout the re-design process: a) improve appearance, b) maintain performance, c) decrease part complexity, and d) reduce cost.

A team of three students from different majors (i.e., Engineering Design Technology, Manufacturing Technology, and Engineering Management Technology) was assigned to this project because it was their first choice. The fact that it was a multidisciplinary team, as oppose to the more typical situation of teams of students from the same major, was as well an excellent opportunity to illustrate real-life settings to the students. The project was to be completed and turned over to the sponsors by the end of the Senior Design class. Recommendations were to be given as well as advice regarding other options that might exist for the redesigned electric nail file.

Methodology

The project followed typical steps in engineering design process:

1. Research the existing devices in the market and identify issues that users might have. A survey was used in this phase.
2. Brainstorm to determine alternatives to address the issues with the initial goals in mind.
3. Evaluate concepts and implement in parametric CAD the top ideas in order to have better visualization and ability to make modification for improvement.
4. Fully develop the selected alternative. All components were modeled using Pro/E (most common software in shops in the area). Models of parts and assemblies, STL files for rapid prototyping, and production drawings for manufacturing were generated. A prototype of the final design was created.
5. Establish materials and financial information. After the materials were selected, the processing techniques were then specified, suppliers were identified, and a cost analysis performed.
6. Specify fabrication procedures, which were kept in mind while making design decisions.

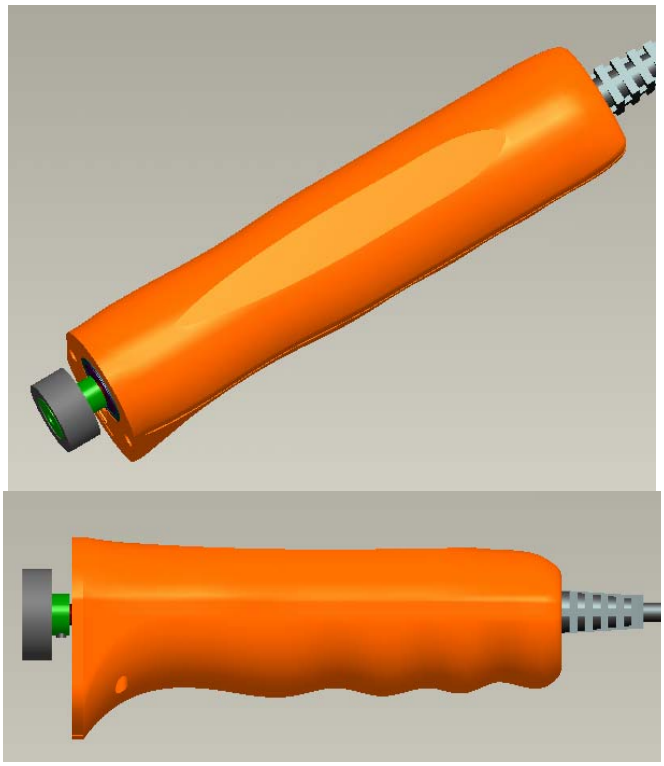

Figure 1: Contouring for proposed design.

Results

With the goal of focusing on appearance, performance, simplicity, and cost, several engineering design process tasks were undertaken:

Survey. A survey was developed in order to identify consumer likes and needs. To do the survey was one of the many learning experiences for the students, both, due to the exploratory nature of the task and due to the realization that there are methodologies and theories behind survey design. The survey was distributed to 30 (semi-)professional nail technicians and to 30 consumers. The objective was to obtain feedback and opinions on electric nail files in general. The surveys also helped us obtain design suggestions. Consistent areas mentioned were: apperance, color, size, attachments, and safety.

Appearance. It was the first and perhaps most important goal for the project, and it was the first one to get addressed. Through brainstorming with the sponsors and based on survey results, a contouring of the body was required. The survey indicated that users want to see more attractive shapes and better appearance on their electric nail files. The contouring consisted of adding finger grips to the bottom of the shell, along with indentions on the side and top. These grips and indentions will allow for a much better grip and appearance (Figure 1). The surveys also reported that a lack of color caused for some disappointment in the appearance. The CAD models have bright oranges and greens to really emphasize appearance, but any color can be specified.

Main Design Features. The *shell* is the largest and most visible component of the electric nail file. Therefore, several features were discussed to try to optimize the design and appeal of the

shell. The size was greatly determined by the required power components, with some considerations about ergonomics (another area of learning for the team). Since the shell has to house all the components, it is impossible to design the shell size to be any smaller than the total size of these assembled housing components. There was also some required space that needed to be provided for the power cable that entered the base of the shell assembly and entered the back end of the motor. These two factors played the largest part in determining the designed size of the shell components. The shell has a top and bottom part (Figure 2), with the top shell being a one piece that includes a front plate in order to minimize manufacturing cost (e.g., molds) and assembly steps and errors. The front plate holds the motor assembly in the proper position. The *ribs* aid in eliminating any vibration produced by the motor, support the motor and housing, and at the same time secure the motor and housing horizontally and vertically. The location of the ribs depends on the overall length of the housing and the motor used. A total of three ribs where implemented in the redesign with additional support from the front opening of the top shell. The front opening in the top shell is where the shaft exits and connects to the drive wheel.

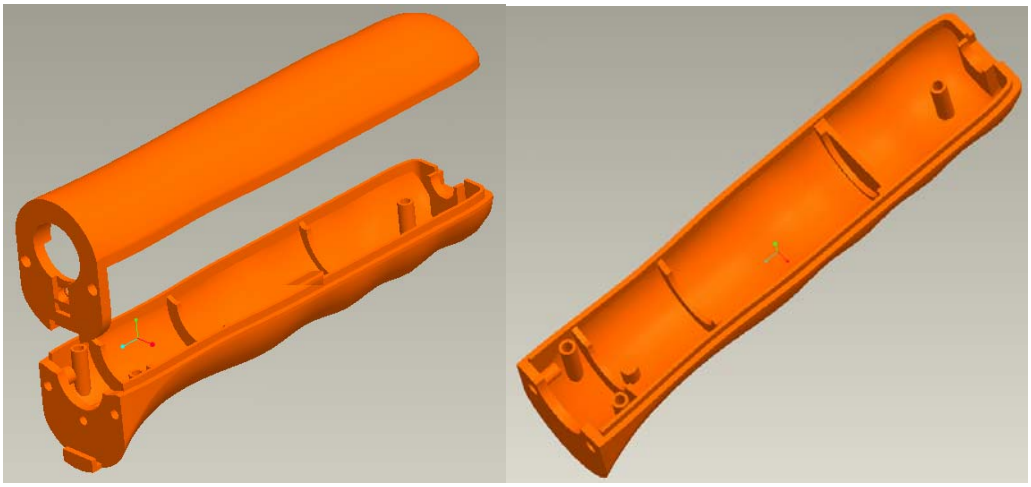

Figure 2: Two-piece shell design with location of ribs.

Material Selection. Choosing the proper material was a very important step in the process. A common material currently used is nylon, with the resulting additional weight when compared to other plastics. Therefore an alternative was selected, Acrylonitrile Butadiene Styrene (ABS) exhibits qualities like ligthweight, durable and easy to handle. Additional properties are: wide color range, high impact resistance, great chemical resistance, and low cost. All of these factors proved to be very important for the proposed product. The wide color range provides design options to please the customer. The low weight helps to solve any tiring problems that occurr from using the a heavier device. High impact resistance allows for the new model to be more durable. This resistance will protect against drops on the floor or banging into other objects that might break or fracture the shell. Good chemical resistance is a necessity because of the sterilizing agents used in cleaning the hand pieces and accessories and attachments. The low cost of ABS helps on the cost analysis.

Motor Housing Assembly. The housing's overall diameter was limited to the available area in the front of the electric nail file. The housing is also used to protect the shaft connecting the motor and the drive wheel and, at the same time, it holds a sealed bearing. The housing (Figure

3) was designed to slip into the front of the top shell opening. The motor assembly aligned the shaft of the motor with the drive wheel that provided movement to the attachments. Because vibration is a reported problem, the alignment of these two shafts was critical. Very tight tolerances were required, and the standard specification used was 0.008 in. There are several other components within this assembly that aid in the aligning of the two shafts. The aluminum housing serves as a base, which attaches to the inside of the shell. This aluminum housing also contains a bearing that centers the shaft, resulting in smooth rotation.

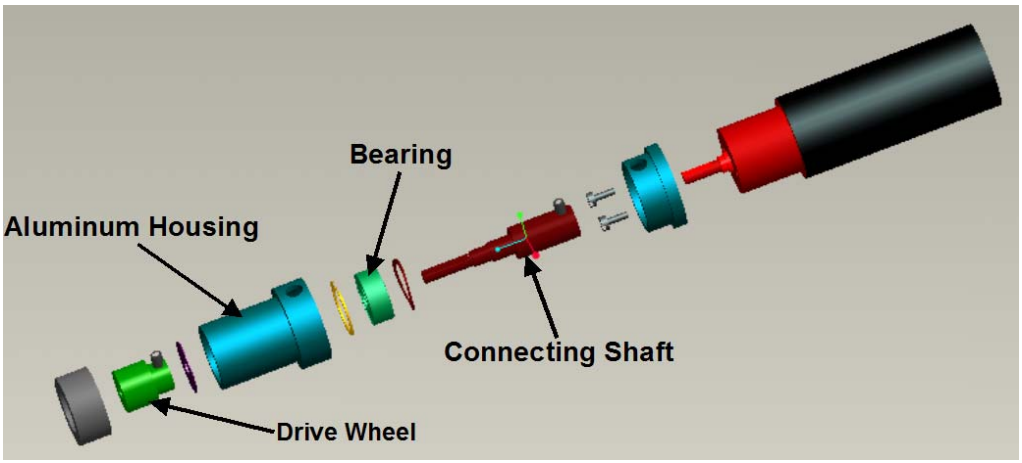

Figure 3: Motor housing assembly.

Assembly Procedure. The assembly procedure determines how the individual components will be put together during fabrication. This procedure primarily focused on the two shell pieces. Fastening with screws, instead of ultrasonic welding, was specified in order to avoid cracked or broken equipment. Also, screws provide adequate strength, making a tight seal possible and allowing for disassemble when repairs are needed. For easier assembly, bosses (two up front and one in the back) were specified. Figure 4 shows an exploded view of the final assembly.

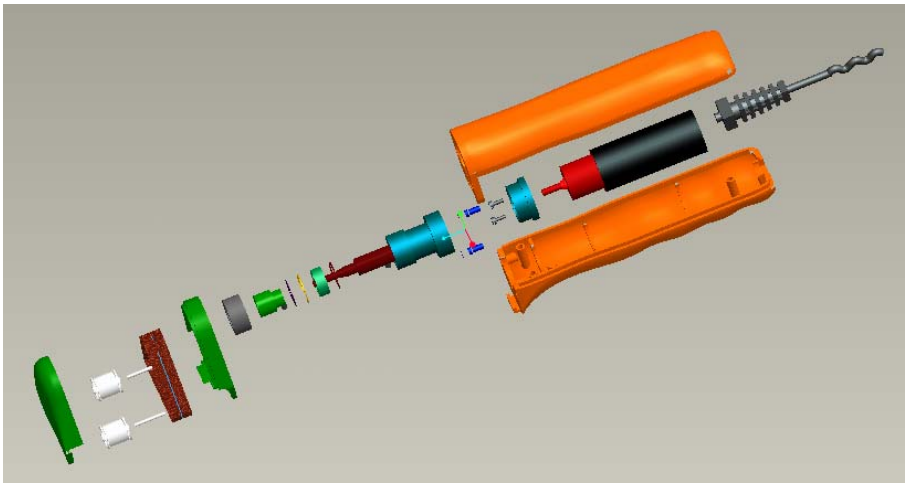

Figure 4: Exploded side view of completed assembly.

Cost Analysis: An important and essential aspect in any new venture is the financials. Table I gives a detailed list and cost of each component for a complete electric nail file. When the supplier for a component has been selected, that supplier has been listed. This task was another

one of the important learning experiences. To communicate with vendors/suppliers and to even do a bit of initial negotiating was an eye-opener to the design team. This activity was a reality check as well for the students had the experience of realizing the impact of globalization in the marketplace. The price advantage when dealing with suppliers from overseas is tremendous (domestic products being over 250% more expensive). The coreless gear motor is the most expensive component in the assembly side, but, at the same time, the one part were huge savings were realized due to an overseas supplier and the opportunity to have the gear-head already attached to the motor. The labor cost was determined by estimating the assembly time per unit and calculating the corresponding wages.

Table 1: Costs based on bill of materials

Bill of Materials For Professional Unit

Qty	***Part No.***	***Description***	***Supplier***	***Unit Cost***
1	SSR-0050	Carbon Steel Spring Washer	Smalley	0.19
1	VH-50	Stainless Steel Retainer Ring	Smalley	0.08
1	SR3-2RS	Ball Bearing	NMB	1.25
1	ESS-105	Aluminum Drive Housing	Promax	2.50
1	ESS-106	Aluminum Motor Mount	Promax	0.75
2	51120.020.004	Stainless Slotted Cheese Head Screw .03ea	Fabory	0.06
1	C/R-1850	Shaft Seal	Zatkoff	0.75
1		Stainless Steel Ground Drive Shaft	Promax	1.50
1	20SYK1312.D	Coreless Gear-Motor	E-Drive Systems	19.85
1	ESS-107	Molded Cord & Strain Relief	Promax	3.20
1	ESS-108	Molded Drive Roller & Aluminum Hub	Promax	1.50
2	ESS-109	T-Insert Cartridge Mounting Pin @ .12ea.	Promax	0.24
1	ESS-110	ABS Plastic Top Clam Shell	Gem	0.28
1	ESS-111	ABS Plastic Bottom Clam Shell	Gem	0.28
2		5-40 Set Screws @ .10ea	G. L. Fasteners	0.2
1	ESS-112	Electronic Control Unit	Promax	18.75
1		1000mA-15VDC Wall Mount Power Sup.	CUI	3.50
1		On/Off Foot Switch	Promax	2.00
2	ESS-113	Lite Touch Cartridges @ .45ea.	JCI	0.90
1	ESS-114	Packaging	Adv. Packaging	1.35
1	ESS-115	Packaging Label	Promax	0.35
1	ESS-116	Warranty Card	JCI	0.02
1	ESS-117	Instructional Booklet	JCI	0.12
1	ESS-118	Explanation of Cartridges	JCI	0.02
1	ESS-119	Accessory Promotional Sheet	JCI	0.10
1		Inbound Freight @ 1%		0.59
1		Labor @ $2.50 per unit		2.50
			Total Cost	**62.832**

Recommendation

After looking at the cost analysis, the main recommendation presented to the sponsors was to have four separate models of the electric nail file. The models are: a) retail level, b) entry level, c) professional level, and d) high level professional. Each of these models offers different unique abilities and features, with speed and overall length being the main differences in the unit itself. The retail model featuring a speed which will be below 1500 rpm, the size is a maximum of 115mm with in-line assembly and no control box. The entry-level model stays at 1500 rpm, with 120mm and basic control box. The mid-level professional model has a speed in the 1700-2000 rpm range and is 130 mm long with in-line assembly and control box. The high level professional model operates at 2000 rpm, size is 130 mm long, with angled head and more sophisticated control box.

Conclusion

This project focused on applying the engineering design process, from need to prototype, to propose a new design for an electric nail file. Research, consumer surveys, and brainstorming were used to determine what issues and aspects would improve the new design. Once these items were established, several task involving modeling, design and manufacturing were addressed. CAD models were used to communicate and illustrate the features of the design, and to show a complete assembly of the proposed design, thus helping in visualization and receiving feedback from sponsors and potential users. Based on economic analysis, the final design was presented with the recommendation to have different models for various market segments.

The project was an extremely interesting and challenging one because it allowed for working with a small business, and due to the need to go into areas (i.e., survey theory, ergonomics, negotiate with suppliers/vendors) not typically covered in the classroom. Overall, based on students feedback, this was a wonderful learning experience were a true interdisciplinary project was carried out. The team had Design, Manufacturing and Engineering Management technology students, thus presenting the opportunity to better interact with an industry sponsor and have a pseudo-realistic engineering environment, as it is expected to be the case in a professional career.

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