This article describes the design of an innovative Automatic Pill Bottle Opener, which was a Senior Design Project in the Mechanical Engineering Department at Stevens Institute of Technology, completed in May 2007.

Automatic Pill Bottle Opener

by Jorge DaSilva, Jay Peterson, Murat Kocak, William Indoe, and Richard Berkof

Project Background

Like most fourth year engineering students, four mechanical engineering students at Stevens Institute of Technology in Hoboken, New Jersey began their senior design project in September 2006. This may not sound significant, but the final body of work more closely resembled a new product development project than your standard undergraduate design project. With a funding grant from ISPE and a total project cycle time of eight months, these students attempted to do what many professionals could not: Find a market need, design a product to meet this need, and transform the final design into a new product reality.

Given the problem statement of designing and developing a semi-autonomous electromechanical product to assist the elderly, the original problem statement was about as vast as the Atlantic Ocean. But before the team could narrow down the scope, it needed to understand its market. The results from the subsequent market research were not surprising. The domestic elderly care and assistance market is one of the fastest growing markets in the world. Within the next 15 years, another 32 million new customers from the older baby boomer demographic will enter this market representing a total spending power of $2.1 trillion. Currently, Americans age 65 or older account for approximately 12.6% of the total population, or roughly 36 million people, with an average expenditure of $3,588 per person on healthcare. This represents a total healthcare spending of $129 billion.

Now that the team had a fairly good understanding of its overall market, a preliminary needs assessment was conducted. Desperately trying to capture the voice of its customer, the team vigorously pursued all avenues. Focus groups held at senior citizen homes, one-on-one interviews with elders, and internet searches for elderly products all yielded several plausible opportunities, particularly in the areas of personal mobility, medication delivery, and memory assistance. Finally with input from potential customers, data captured from market research and lengthy brainstorming sessions, the group identified a need for an automated medication container opener.

The automated medication container opener was targeted at individuals suffering from arthritis, cerebral palsy, muscular dystrophy, or any other cause for general muscle weakness and reduced grip strength. Such individuals tend to have difficulties opening standard childproof closures found on most medication containers. Thus, the team’s new objective was to facilitate the opening of medication containers through the development of an electromechanical consumer device. The goal was to provide a universal solution for removing these medication container closures.

In addition to simply fulfilling a need, the team felt that this product also presented a great market opportunity. Consumer models
that exist in the current market are not fully automatic. Most consumer models are simple manually assisted devices that require a large amount of dexterity and strength from the user. If a fully automatic device could be designed and built, it would enjoy a huge competitive advantage as being the first such product to market.

**Preliminary Design**

With a customer need and market opportunity identified, the team could now enter the initial design phase. Knowing how important customer satisfaction is to the success of a consumer product, the team needed to ensure that the final design would satisfy the customer’s needs and wants. To achieve this, the team developed a House of Quality Matrix - Figure 1. The matrix takes engineering characteristics listed in the top row of the matrix and compares them to the customer requirements listed in the leftmost column. In the cell where the customer requirement intersects the engineering characteristics, the level of interdependence is denoted by a symbol or number. Ranking the customer requirements in order of priority and then seeing which engineering characteristics correspond to the higher ranking requirements, the team is able to identify areas of the design in which to focus. For this project, the top three ranking customer requirements were ease of use, cost, and appearance.

Now that important engineering characteristics were identified, the next step in the process was to develop a product scope and specifications for the design. With the original goal of developing a universal fully automatic device, the team tried to make the scope as wide as possible without biting off more than they could chew. Thus, they decided to include all types of medication containers they could. The types of containers included in the scope were child safety, standard screw off, and pop top containers. The only containers omitted from the scope were the child resistant containers featuring two tabs on the side of the cap across from each other, which the user depresses in order to unlock the safety mechanism.

Specifications such as the cap and bottle dimensions and closure type were determined through researching the different types of medication containers that exist. The values were acquired from manufacturers of the medication containers. Specifications such as the machine dimensions, weight, opening time, and loading time were determined from feedback that was provided by the customers. The customer research showed that the consumers desire a product that is similar to
conventional home devices such as a coffee maker or a microwave. The opening time must not exceed 30 seconds and loading time must not exceed 20 seconds. The remaining specifications such as opening torque and minimum down force were determined experimentally. After performing such experiments, it was found that in order to depress a standard child safety mechanism, a minimum of 11 pounds of down force must be applied. In addition, the minimum torque required to open a bottle was determined experimentally to be about 1.5 inch-pounds.

During the next phase of the project, the team brainstormed several different concepts and developed hand sketches of these concepts, such as the one shown in Figure 2. Based on the highest ranking customer requirements and the important engineering characteristics identified in House of Quality, the team was able to perform a concept screening to choose the best concept. The sketch shown is actually the winning concept that was selected for further development. It features a crosshead that travels vertically downward to engage the child safety mechanism. The bottle is centered using the lower grippers and then the crosshead rotates to open the container.

Design Development

After two and a half months of work, several discussions, and a few disagreements, the team was ready to begin its detailed design. With the customer needs always in mind and focusing on the critical engineering characteristics, the team was able to utilize advanced 3D modeling software packages to develop a detailed design. Figure 3 shows an exploded view of the final detailed design. Somewhat different from the original sketch, the final design does not use fingers to physically hold the cap after it is loosened. The team felt that a user would not want the machine to retain the cap after the bottle is opened. This also helped reduce complexity in the design as it reduced the number of moving parts.

The final design features a bottom gripper operated by the rotation of an internal cam. This gripper is only used to center the bottle and does not need to firmly grasp the bottle once the crosshead is engaged. A linear lead screw is used to raise and lower the crosshead as well as provide the necessary down force to depress the child safety mechanism. This linear lead screw is operated via a stepper motor. The final motion, which is the bottle rotation, is done at the crosshead and is powered by a standard permanent magnet DC motor.

The advantage of using a 3D modeling program is the ability to perform stress analysis on the various parts that make up the assembly. This allowed the team to verify the integrity of the design and make design changes quickly based on unfavorable results. The screen shot was taken from one of these analyses performed on the internal cam mechanism of the assembly - Figure 4. The team identified this component as having a high potential for failure; thus, the team used the software to verify that its design would not fail under the stresses and strains of operation.

Final Design, Fabrication, Assembly, and Integration

A final design was now in place, critical parts were identified and analyzed, and the team had four months remaining to
fabricate and test the design. During these remaining four months, the team was able to order and receive all components, machine those that needed machining, perform a detailed electrical design, program a microcontroller, assemble all of the sub components, and test the machine’s functionality. After a successful integration phase, the result of this effort is shown in a fully functional proof of concept device capable of gripping, engaging, and rotating caps off a wide variety of medication containers - Figure 5.

Industrial Design
The major aspiration of this project was design, build, refine, and test the proof of concept device to highlight the feasibility of our concept for an automated pill bottle opener. The team decided that it also needed to demonstrate that the concept has a marketable aspect to it. Thus, a consumer design was required to reveal the next rendition of the group’s concept; the design incorporated all the knowledge of the mechanics of
opening various caps that the group had learned from testing and refining the proof of concept design. The consumer model can be seen in Figure 6. Some major changes are the sleeker outer casing, which would be made of injection molded plastic. This helped significantly reduce the number of fasteners necessary for assembly, reducing assembly time. The casing also helped considerably reduce size and weight. The power transmission mechanism also was changed on the lower gripper of the consumer design from a belt and pulley to a gear train.

This consumer model also was important to help determine the economic feasibility of the project. Market research showed that price was the primary concern for consumers. It also showed that there was a willingness to buy the product if it could be offered at approximately $75. Based on revenue projections, manufacturing cost estimates, and start up expenses, this initial investment could generate an IRR of 33%, a Net Present Value of $1,778,000, and a payback period of 4.1 years. The cost of the product is reasonable, considering many devices on the market are manual and can cost up to $30.

As people age, they lose some of the physical functionality they had at younger ages. As this begins to happen, they become more dependent on others to help them complete daily tasks. This device will allow elderly individuals to retain a level of self-reliance, which could enhance their overall quality of life. Not such an insignificant accomplishment for eight months work from a group of highly motivated undergraduates.

**Note About the Project**

This project was supported by a generous grant from the ISPE New Jersey Chapter, of which the associated Stevens Student Chapter is the active organization on campus. The Senior Design Project concept and working model were presented at the 2007 ISPE New Jersey Student Poster Contest, and won first place/top honors.

**References**


**About the Authors**

Jorge DaSilva graduated top of his class from Stevens Institute of Technology in Hoboken, New Jersey, in May 2007. He received a Bachelor’s of Engineering in mechanical engineering, along with a Master’s of Engineering in systems engineering. After graduation, he joined Johnson & Johnson’s Global Operations Leadership Development Program (G.O.L.D.). As part of his first rotation, he is working as a Mechanical Engineer in the Engineering Technology

Concludes on page 70.

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