Three Phase Optimization of a Label Application Device for the Visually Impaired: Design, Implementation Analysis, and Modification

Caitlyn Collins, Justin Gearing, Dan Miller, Jamon Opegnorth

University of Wisconsin Madison, Biomedical Engineering Design Team

Abstract: This paper includes the design and analysis of a manual label application device. It details the assessment of an ineffective method of application, being implemented by a small manufacturing company, and the production of prototype designed to increase overall efficiency and accuracy of label placement. Discussed is the preference of manual label application over complete automation of the process and at the end, a detailed summary of all testing results, findings, and future work will be given.

1 Introduction

This paper introduces and offers an analysis of a new device used to apply labels manually. The development of the aforementioned label application device is broken into three phases; design, implementation analysis, and modification.

In today's packaging and assembly services, there is a need to improve the ergonomics and efficiency of manually applying a variety of labels to smaller products, such as a lawnmower engine shroud. Improving the ergonomics of this process is especially important for a workforce that contains a majority of employees with visual impairments. The time it takes to finish a product on these lines is too long and the amount of scrap produced is too high. This leads to increased costs in materials used, quality productcontrol, and loss of time employees could use for other services.

The process of applying labels onto a product can be separated into two main categories: automatic and manual. In an automated system, a machine will apply the label to products moving along a conveyer belt; no employee is needed for the application of the label. This process greatly increases the productivity of products produced while maintaining high accuracy. However, these machines are often very expensive, costing $8,000 for a low end machine. These machines also are not versatile when it comes to changes in the product. Manual application of labels involves a person physically pressing a label onto the product. This process is more time consuming and is more susceptible to errors. However, this process does not require expensive machinery and is also more conducive to changes in products as well as applying labels in odd locations.

As the current method being employed by a company does not yield results that reach production goals, the generation of a device or streamlined process is required in order to keep up with the ever more competitive industry standards in this tight financial climate.

2 Three Phase Optimization

In order to achieve an increase in accuracy and production, the first step will be to analyze the current application protocol in order to determine the best means of improvement. After the initial analysis, a comprehensive list of design constraints can be created to dictate the actual design phase. The design can then be tested in comparison with the existing protocol to determine its level of success. Modifications can then be made, based on the test results in order to fully optimize the system.

2.1 Design

Initial Assessment

The main solution thus far to keep production rates acceptable and re-work costs lower has been to use only employees with limited visual impairments. This solution does not help to make the process more universal to all employees nor does it actually improve the process. Other solutions include makeshift devices that are able to provide assistance to users, but only to those who do not have higher degrees of visual impairment. Figure 1 depicts a modified device created to facilitate completely blind employees. When used, it fails to yield the desired success rate; therefore, a new device and process have been developed in order to allow all employees to complete the process of applying labels with greater efficiency than they were previously able to. The device was tailored to engine shroud covers produced by Briggs & Stratton. The main concept the new device was to eliminate the need to have the user place the label directly onto the product, and instead have the user guide the label onto the product using the assistive device.

Figure 1: Original Device
The template used for a completely blind worker requires larger cut outs, in order to accommodate their fingers, resulting in less accurate label placement.

Design Criteria

In order for such a device to be successful in a factory setting where vision is not needed, the device was designed to not harm the user. Second, the device was designed to be no larger than 0.305 m x 0.305 m by 0.305 m as to allow for easy storage and transportation. Third, the device was designed be able to withstand 500 uses per day, with replaceable parts. Fourth, the device was designed to prevent the build-up of dust by allowing all areas of the device to be easily accessible. Finally, the overall process of applying the labels to the engine shroud shouldn't be any more complicated or time consuming than that of the current process.

Manufacture of the Prototype

To validate the concept of the new design, an intermediate prototype was first fabricated. The prototype uses a prefabricated plastic template of the Briggs & Stratton engine shroud. The template is inverted and attached to a spring system shown in Figure 2. The figure shows the template fixed to an aluminum plate which is supported solely by the two spring columns. The columns are composed of polyvinyl chloride tubes; with the inner diameter of the outside tube is just larger than the outer diameter of the inside tube. Together the tubes make a column that supports bending stress, while allowing the column to change height with minimal restraint. The support for the compression of the column is provided by one spring in each column, however this resistance can be easily overcome by the user.

Figure 2: Template and Spring System
The template is fastened to the spring support system. The spring allow for the template to move up and down.

Pedestals were fabricated that protruded into the arrow cutouts on the template so that the top of each pedestal is just below the top surface of the template. Figure 3 shows the pedestals protruding into the arrow cutouts on the template. This allows for minimal horizontal translation of the sticker once applied in the template cutouts, holding the labels in place.

Figure 3: Template with Pedestals
The pedestals sit directly below the template, and protrude into the arrow cutouts.

The prototype also incorporates ideas that have been previously used in sticker application production lines such as the use of a vacuum system for handling stickers (Piab, 2010). The vacuum used for the prototype is a Gast 115V vacuum/compressor (model DOA-P704-AA) capable of generating almost -25 mmHg pressure. This vacuum was selected because of its availability and it was well under the (85 dB- OSHA guidelines) limit for prolonged exposure. This particular vacuum is undersized for this application, which created a need for a valve for each of the pedestals. The valves isolate the vacuum pull to each pedestal which allow adequate suction in the pedestals by isolating each pedestal allowing for all of the suction power to be allocated to each pedestal individually.

2.2 Implementation Analysis

Testing Procedure

The comparison testing of the prototype and prior method of application were done in house. To properly evaluate the effectiveness of the new design, the company's engineering staff observed visually impaired employees performing the label application process for the original protocol and the developed prototype in September 2010 and December 2010. The original protocol was tested using a long-term in process monitoring (IPM) study, while the testing of the prototype was conducted over a shorter period of two hours. The engineer leading the study recorded the success/scrap rate, the number of completed parts, and the time needed to complete.

As mentioned, the original protocol required the user to mount the engine shroud with a template onto an aperture, to hold it in place, and then the cutouts within the template were used to guide the placement of each individual sticker. The stickers were applied one at a time after removal from a wheel stationed adjacent to the fixing aperture. For the prototype, the vacuum was engaged at the start of the testing time and remained on until completion of the study. The first step in prepping for application of the stickers, using the prototype, involved narrowing the pull of the vacuum to a single pedestal using the manual valves. A sticker would then be removed from an adjacent wheel and placed sticky side up within the pocket created by the interface between the template and the pedestals. Once in place, the vacuum pull to the next pedestal would be engaged via the manual valves and the process would be repeated until all three stickers were in place. After all the stickers were in place the shroud would be fitted into the template. Finally, application of a downward uniform pressure onto the shroud applied the stickers onto the shroud.

Initial Results

The testing process in September 2010 was conducted as a long term IPM study. The employee was able to complete 12 shrouds per hour at an average completion rate of 4 minutes and 46 seconds per shroud. There was a success rate of only 32%, resulting in a large amount of rework materials. During this process, the employee spent the majority of their time trying to find the proper location and orientation for each sticker.

The testing process in December 2010 utilized the new prototype developed in Fall 2010. The employee was able to complete 22.5 shrouds per hour at an average completion rate of 2 minutes and 31 seconds. The success rate was 100%. This new prototype allowed the employee to identify the proper location and orientation of the labels faster than the previous method. This study was conducted for 1.5 hours. Table 1 provides a summary of both test results.

Test	Sept. 2010	Dec. 2010
Accuracy	32%	100%
Parts Per hour	12.5	22.5
Time	4.75 min	2.51 min.

Table 1: Testing Data. A summary of testing data for the original protocol and the initial prototype.

Design Changes

Testing of the initial prototype afforded the design team with insight into potential changes that could increase overall efficacy. The design components most in need of modification include the limited vacuum power, the tubing that interferes with a seated user, and the ergonomics of the total system.

As the vacuum used was undersized, requiring the use of manual valves to compensate, incorporation of a stronger vacuum will eliminate the need for such valves, directly reducing the number of tasks required for the entire application process. This further optimization is expected to result in an increase the rate of production.

The protruding airlines, out the front of the prototype, take up excess space and also hinder the devices ability to rotate. As the application device will be utilized for variety of engine shroud models, the application of side stickers as well as the arrow stickers may be required. A rotating device would allow for simple side sticker application. Implementing a manifold system incorporating the arrow pedestals with an internal vacuum channel system, having a single output exiting the device through the center of base, would allow for easy rotation about the center while at the same time eliminating the cluttered tubing.

After evaluation by outside source ergonomic engineers, it was determined that a shift in the working plane would greatly benefit the user. This could be achieved by mounting the device at an angle so that the working plane was directly in front of the user, rather than at a 90^o from their body, reducing strain in the user's wrists during operation.

2.3 Modification

Ergonomic Redesign

The ergonomics of the redesign were of utmost importance, as the final design would be used by the same person for as much as eight hours a day, while still maintaining the achieved level of accuracy and efficiency of the initial prototype. The final design would also ideally allow for increased customizability, as the previous prototype would likely have to be scrapped with any shroud changes by Briggs and Stratton.

New Design

Manifold

After evaluating last semester's prototype there were several changes that helped enable us to create a better final product and address our new design criteria. One of the most significant changes this semester was eliminating the valve system and tubing from the prototype. This was accomplished by incorporating a manifold system (Figure 4) that allows the system to pull a vacuum on all three pedestals from one central line. The manifold chamber is large enough to allow for adequate flow for the vacuum. The manifold is made from two pieces so the top piece could easily be replaced if Briggs and Stratton were to change their shroud design. In order to ensure a proper seal, there is a rubber gasket in between the two pieces of the manifold, which are bolted together. The elimination of the excess tubing reduces the cluttered working environment, yielding a device that is easier for a worker with visual impairment to maneuver.

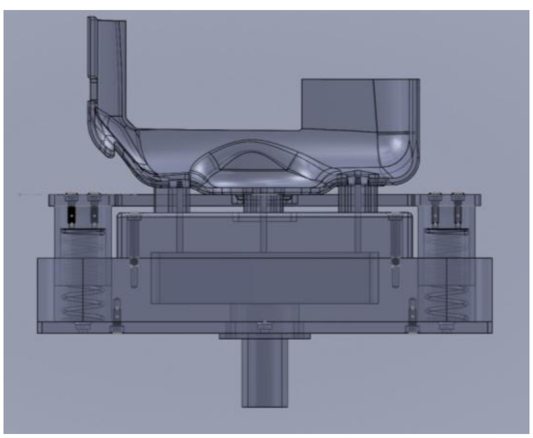

Figure 4- Manifold system.
Adjacent pieces are held together by screws and sealed with a rubber gasket to ensure the vacuum throughout the device is maintained. This creates an internal channel system eliminating the need for valves.

Material selection

The materials selected for the final design were ideally lightweight, yet strong and durable enough for extended use in a factory setting. 6061 aluminum was selected for most components due to its relatively low density as well as ease of fabrication. The shroud template is rapid prototyped from ABS (Acrylonitrile Butadiene Styrene). The springs are steel due to their function and relatively low size.

The spring legs are machined from Acetal, as it offers high strength and a low coefficient of friction, which is ideal considering how the part is used in the device. With incorporation of material with a low coefficient of friction and springs with low stiffness coefficients, in the moving component of the device, the force required to operate the device will be minimized, preventing the development of overuse injuries in the company's employees. All other components are machined from aluminum stock.

In order to help ensure the long-term durability of the device, design changes were made to reduce the stresses on certain parts of the device, mainly the spring legs and their associated mates. In the previous design, the spring legs sat behind the pedestals, such that a bending moment was generated when the user applied a force a distance away from the neutral axis on the shroud. To eliminate this bending moment, and the associated compressive and tensile stresses, the spring legs were moved to the side of the pedestals such that they are on the same axis as the applied pressure. This change effectively eliminates the bending moments in the spring legs generated by the user as well as increased the overall ease of use.

In order to improve the ergonomics of the prototype, two major design changes were made. The first of which, changing the device such that it sits at a 15° angle (Figure 5), was inspired by federal engineers that assessed our design. This rotates the work plane directly in front of the user's body resulting in a reduction of the strain within the wrist, as pressure is now applied to the device with the wrists in a more neutral position (Muggleton, *et al.* 1999). The tilt also increases the user's ability to operate the device effectively. The second change involved mounting the base plate on a turn table such that the entire device can easily be rotated around. This allows the user to easily apply the side stickers to the shroud in a time efficient manner. These changes, as well as the elimination of the valves and tubing should help the users increase the throughput without complicating the operating procedure and maintaining ease of use.

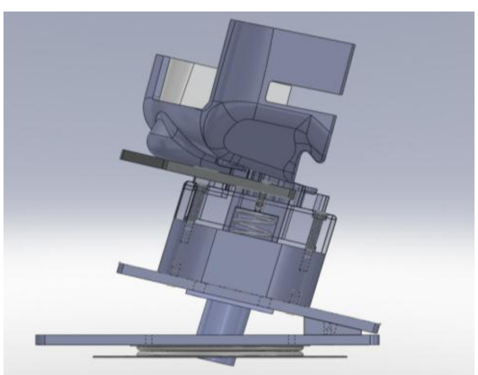

Figure 5 – Ergonomics and Additional Improvements
The entire device was raised to a 15° angle to move in the plane of the worker. The springs were previously mounted at the front of the template shroud, where a large moment was created when pushed. A turn table has been added to allow for placement of side labels on 5-label shrouds.

Final Testing

In April 2011, similar testing to the abovementioned process was conducted on the new prototype in order to determine if any of the design changes were counterproductive to the overall goal of optimization. The testing was conducted over a period of one workday, far exceeding the test time of two hours for the testing of the original prototype.

Final Results

The testing process in April 2011 used an advanced prototype similar to the Dec. 2010 version, but without the valves. The employee was able to complete 19.83 shrouds per hour at an average completion rate of 3 minutes and 1 second per shroud. The success rate was again recorded at 100%. This study was conducted over a period of 10 working hours. Table 2 provides a summary of all three testing sessions.

Test	Sept. 2010	Dec. 2010	April 2011
Accuracy	32%	100%	100%
Parts Per hour	12.5	22.5	19.83
Time	4.75 min	2.51 min.	3.03 min

Table 2: Testing Data. A summary of testing data for the three different types of prototypes.

The testing shows that there is a significant increase in the accuracy and efficiency of the process from September to April. There is a slight drop in production rate between December and April. This can be mainly attributed to a small test sample size conducted in December. The April statistics are more accurate as the study was conducted over a course of 10 hours rather than 2. Production rate is expected to increase as the employees become more experienced with the new process.

5 Conclusion

From the basis of the testing data, it was concluded that the label application device achieved the desired optimization. Further utilization of the device, by individual employees, will most likely increase its efficiency over time as a familiarity with the system is developed. Although the device has proven to be extremely successful in an environment where the workforce is mainly visually impaired, it has the potential to be implemented in more traditional working environments as well. As mentioned before the cost of a fully automated system is very expensive upfront and is fairly limited in its abilities to conform to changes in application geometry. The major convenience of the manual application device created is its robustness when it comes to changes in either the shroud or sticker geometries.

For future work, an IPM study should be conducted on the final prototype in order to determine if the higher accuracy and efficiency recorded, in the relatively short term studies, is consistently achievable.

References

Piab. (2010). *Pharmaceutical.* Retrieved on 12/7/10 from http://www.piab.com/en-us/industries/pharmaceutical/

United States Department of Labor- Occupational Safety and Health Standards: "Occupational Health and Environment Control" 1910.95 App G. March 1996. Retrieved from http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9742

Muggleton, J.M., Allen, R., Chappell, P. H.; "Hand and arm injuries associated with repetitive manual work ain industry: a review of disorders, risk factors and preventive measures." 1999 **Ergonomics** Vol 42:5 pp 714-739.