ABSTRACT

This project involves the design and creation of a jig which will aid in the manufacture of pallets and crate bases. The project sponsor, A.C. Packaging, builds pallets of a custom nature, and their current jig does not adapt to these changing needs. The redesigned jig utilizes pneumatics to move platforms to create pallets of a variety of configurations. Design, manufacturing, and testing of the jig will be discussed in order to properly explain the results of the prototype.

NOMENCLATURE

To eliminate confusion for those inexperienced with pallet terminology, some common terms are defined below. In addition to the short glossary, a visual aid is included in Fig. 1.

Runner: Piece of wood in a pallet which runs the length of the pallet. This jig is only concerned with runners which are dimensionally close to 2x4s. A minimum of 2 runners and a maximum of 3 can be employed.

Deckboard: Thin, flat piece of wood which is fastened to the runners to create a flat surface on the pallet. The deckboards span the width of the pallet. They can be above the runners, below them, or both. Their width, thickness, length, and number can vary.

Standard Pallet: Pallet in which the deckboards are flush and square with the runners. Usually have at least some bottom deckboards.

Wing Pallet: Pallet in which the deckboards extend beyond the ends of the runners by a specified distance. A wing pallet can have wings on one side or both. It is not common for wing pallets to have bottom deckboards.

INTRODUCTION

The objective of this project is to design and build a semi-automated, reusable jig to reduce the time required to size and create pallets. This need will become clearer after reviewing the jig currently in place.

A.C. Packaging is a small company which specializes in creating custom pallets and crates for shipping purposes. Due to the custom nature of this work, small runs of pallets with unique sizes and styles are most often handled. They also run a fairly low-budget operation, as shown by their current jig.

The sponsor’s current method of making pallets utilizes a crude, wooden table as a pallet jig. There can be either one or two employees working on each run of pallets; generally pallets with a length greater than 36” (914.4 mm) require two people. The workers stand across from each other on the width sides of the pallet. The pallet style and dimensions are given to the employees on the job, and they measure to determine where the runners must go to create a pallet as sized to the order. The
workers then nail pieces of wood to the table in such a way as to act as runner (and wing if necessary) stops. Having done this, the runners can be brought over and set against the stops.

The deckboards are then brought over to the table. It should be noted that deckboard widths and heights, as well as their quantity, differ from pallet to pallet. The deckboards are set in place on the runners and nailed down using pneumatic nail guns, starting with the members on the ends of the pallet. They are nailed from the sides in towards the center. The operators use their hands to hold each runner flush with the stop as they nail it in. After the end boards are nailed, the pallet is measured across the diagonals to make sure that it is square. If it is not, the deckboards must be pulled off and nailed again. If the pallet is square, the remaining deckboards are nailed to the runners.

The pallet is then flipped (if necessary) to nail the deckboards underneath the runners in place. The workers must make sure the pallet is on a flat surface, or they can be struck by a nail during a “double-nail”. This happens when the pallet is not well supported and bounces back up into the nozzle of the gun during nailing. This causes the gun to fire a second, uncontrolled nail. This is a dangerous situation which has been the cause for past accidents, so it is imperative that the pallet be ample support when flipped. After the process is repeated for all of the pallets of the given run, the runner and wing stops are pulled off and re-nailed to correspond to the dimensions of the next run.

Working in the same building as the project sponsor is Phenix Automation. Phenix is a distributor of both the Bosch extruded aluminum profile system and various lines of pneumatic equipment (Versa, Allenair, American Cylinder, Pisco…). Matt and Eric of the design team are currently employed by Phenix, and the team decided early in the design phase to utilize the various resources made available by the company.

**PROBLEM DEFINITION**

Early discussions with the sponsor revealed that building pallets is not problematic; the workers are very quick and do good work. It was expressed, however, that the current time required to set up their jig was unacceptable.

After close study of the sponsor’s current pallet-making method, a block diagram was used to create a graphic of the process. From this diagram many “hidden” sources of lost time (operators dropping their nail guns to the floor and picking them back up again) in the current method were realized. This insight helped to give the team specific goals to achieve instead of open-ended statements.

In addition to this, careful attention was paid to the sponsor’s ideas and input. Perhaps the greatest need stressed throughout the project was to be sure that the solution being created was the solution the sponsor desired. During each major and minor project milestone, time was spent contemplating the team’s progress in relation to the sponsor’s wishes. The needs assessment, then, was an often-sourced compilation of rules, and it was essential that they be laid down right from the start. From the needs assessment, major and minor project specifications were generated. The major specifications were critical to the project’s successful completion and are included in Table 1 below. The minor specifications are more like improvements to tweak the working model with. They include things like ergonomics and aesthetics, which manifest themselves in the prototype.

**Figure 2: Current Jig**

![Current Jig](image)

**Table 1: Major Project Specifications**

1. Jig must be able to build pallets 20” – 48” (508 mm x 1219.2 mm) wide x 24” - 64” (609.6 mm x 1625.6 mm) long.
2. Jig must be able to build pallets of different heights.
3. Jig must be able to incorporate wing sizes from 0”- 6” (0 mm - 152.4 mm).
4. Jig must be able to fasten deckboards to bottom of pallet.
5. All components must be held within running lines of jig.
6. Jig must be a portable, self-contained unit.
7. Jig should be able to run off of compressed air (preferred).
8. Jig must be safe (among other hazards, provide pallet support so as to prevent double-nailing).
9. Training time must be minimized (≤ 30 minutes).
10. Jig must cut current setup time (~15 minutes) by 50% or more.
11. Jig must be robust enough to handle sponsor’s work environment (extreme temperatures, sawdust, impact loads…).
12. Pallets must not bind up in jig upon removal.
13. Pallets must be square to 1/16” (3.2 mm) tolerance.
14. Jig must be repeatable.
15. Must minimize cost (≤ $1500).
16. Jig must be operable with two workers or less.
17. Jig design to minimize maintenance costs.
18. Jig must be able to handle runner widths ranging from $1/8" – 1/2" (35 mm – 38.1 mm).

From the needs assessment, a mission statement was created to narrow down the aims of the project. This statement performs such critical tasks as defining scope, success qualifiers (essential criterion), and success winners (secondary criterion). It is also helpful in identifying primary and secondary markets.
for the solution, which are not seriously considered by other project-organizing algorithms. The mission statement reinforces the realization that there are many constraints on this jig. Time, cost, flexibility, portability, efficiency, ergonomics, safety, user-friendliness, accuracy, and robustness are among the key jig considerations. This statement also highlights the fact that the jig must be completed as a fully-functional tool, ready for daily use by the sponsor at the close of the project.

At the same time that the needs assessment was being generated, the team was engaged in benchmarking existing pallet jig solutions. Due to the custom nature of the jig and its requirements, the existing designs found were not significantly helpful to the team. The vast majority of pallet jig solutions found were concerned with big, expensive machines designed for large runs of standard pallets. Emphasis on quantity (not ease of adjustment) was the general consensus of the existing product. The research was a good exercise, though, because it helped the team to further hone in on how to complete the task at hand.

In addition to the needs assessment and mission statement, several other algorithms were used to fully define the problem. An objectives tree served as a graphic needs assessment, and revealed how the project specifications depended on one another. Pairwise comparison and QFD analyses were implemented to prioritize the specifications and correlate them to design metrics. Feasibility and risk assessments were done on the project as a whole to try and predict where the project could falter. Using this, a Gantt chart was made to serve as a project timeline and track progress. At this point, the project is fully defined and ready for the design phase.

**JIG DESIGN**

While constantly referencing the problem definition and the sponsor’s wishes, the team started the task of coming up with the solution. A logical, iterative approach was used to generate and perfect the design concepts. The final system was divided into six main subsystems: the runner stops, the User Input System (UIS), the wing stop, linear guides, actuation, and the base. Ideas for the subsystems’ construction and operation were generated using morphological charts and brainstorming. At this point, another round of benchmarking was done for each subsystem. The ideas were then discussed and the best three for each subsystem were selected for further analysis.

In order to optimize the ideas generated, a three-part analysis was done on each of the three subsystem concepts. First, a risk assessment was done on the subsystem to determine what types of systems and components would be more robust solutions. This generated critical questions, which were used to compare the concepts in a feasibility assessment. Each concept received a score based on how well it fit the subsystem requirements compared to the other two ideas. At this point, it was usually clear what the optimum solution was, but another analysis was done to be sure. The results of the feasibility assessment were taken and scaled against the baseline (existing) jig’s counterpart subsystem. This helped the analysis stay true to the main focus of the project: improving the setup time of the current jig as much as possible.

**RUNNER STOPS**

The runner stops were considered by the initial project risk assessment to be one of the more critical project components. Their design is responsible for mitigating the double-nail hazard by providing ample pallet support when flipped. It is also one of the more heavily used jig subsystems, so it must stand up to the test of production. The team conceived a recessed stop which would capture the pallet runner in a channel. As shown below in Fig. 3, the stop was intentionally made wider than necessary to support a flipped pallet. At the same time, it was made narrow enough so that there is not a physical limitation when the stops are moved to the smallest configuration possible, the minimum pallet size of 20” (508 mm) can still be achieved. The stop was designed to be built using the Bosch extruded aluminum profile system and having the pieces connected via join plates and end plates. The aluminum strut was chosen for its high strength-to-weight ratio, professional appearance, and availability with purchasing discount through Phenix Automation. Ball catches were installed in the side of the channel to hold the pallet runner in place. This also makes the jig safer to use, as the operators no longer need to hold the runners in such close proximity to where they are nailing. Safety yellow cover strip is used to denote the presence of moving parts, further exemplifying attention to such details. The end plates incorporate slots which line up with the pallet runner channel. When the runners are inserted and pressed against the plate, they will force sawdust out the front of the jig. This, coupled with an air blower, will prevent sawdust from throwing the pallets out of square.

**USER INPUT SYSTEM**

The jig must be able to be quickly and easily sized for any pallet in the required range. Thus, the operator must have an accurate, easy-to-use system to input these configurations. After a thorough analysis, the team decided to implement what they call the pin-cam UIS system to this end. This system utilizes two pins and two pneumatic cam-lever limit switches. The pins are fastened to a manual toggle clamp, which can move back and forth in a slot via a slider bearing. A tape
measure located above the pin slot would let the user choose a pallet width to input. The operator would move the two pins to the correct position to make the required pallet, and then lock them in place with the clamps. Attached to the underside of each end runner stop is the pneumatic limit switch, placed in line with the pin. When the jig is activated, the runners would move inward until the cam sensor contacts the pin. At this point, the limit switch would send a signal to the actuator to stop, and the jig would be sized according to the pin placement. This system is dynamic and easy to use, as the requirements indicated that it must be.

A great deal of time was spent devising a way to synchronize the two width pins: that is, moving one of them would move both of them. A linkage system was conceived but not considered satisfactory. The team would look for opportunities during construction to implement this synchronization.

WING SYSTEM

It was stated by A.C. Packaging that pallet wings always occur in increments of 1” (25.4 mm), and never greater than 6” (152.4 mm). Thus, there are only seven (counting zero) different settings the wing adjustment needs to account for. This is in comparison to pallet widths, which there are an infinite amount of configurations between 20” (508 mm) and 48” (1219.2 mm). The type of flexibility offered by the limit switches was not required here. Instead, the wing was to be situated on two slider bearings like those holding the UIS clamps. Attached to the moving wing are two spring plungers, as shown in Fig. 5. Underneath the plungers are pieces of aluminum angle with seven holes, one for each discrete wing setting. The holes mate with the plungers to form the required wing sizes. At the zero setting, the wing serves as a positive stop to help align the left runner. The entire wing system can also be completely removed from the jig by loosening two bolts. This discrete, low-cost solution is much less automated than the UIS; however, it was chosen by the sponsor because its similarity to the existing jig’s wing makes it easy to train the operators on.

LINEAR GUIDES

The linear guides perform two important tasks: support the runner stops, and provide a smooth path for them to traverse the jig. The team researched a variety of linear guides, most of them being high-end in terms of accuracy and cost. As a result of the three-part analysis, it was decided that Bosch EcoSlides would provide the channel of movement for the runner stops. The EcoSlides were the most inexpensive option, and the limited budget was definitely a factor in the analysis. In addition, they are readily available through Phenix, move very smoothly, and are easy to install and maintain. The linear guides are shown below in Fig. 6. The EcoSlide is an aluminum carriage designed to ride on the Bosch extruded aluminum. Separating the EcoSlide and the strut are Delrin slider bearings. The sliders are fastened to the inside surfaces of the carriage. The carriage can then slide back and forth in the T-slots of the aluminum strut via the bearings. The Delrin bearings will ensure smooth and effortless translation of the runner stops. However, the T-slots in the strut must be guarded from debris, or the linear guides may bind up. Bellows were found for this purpose.

The runner stop is the load which the EcoSlides will have to endure, so a free body diagram of the stop was constructed to determine the loading on the slider bearings. This diagram is shown on the following in Fig. 7. The guide is shown to have three weights on it, or one for each runner stop. Each runner guide will have a distance associated with it (a, b, c) and this distance will change depending on the size of the pallet to be...
made. The center runner guide is to be fixed by design: therefore, \( b = \frac{1}{2} \).

Figure 7: Free Body Diagram of Linear Guides

Performing a static analysis and solving for the reactions yields:

\[
R_2 = \frac{1}{LN} (aF_1 + bF_2 + cF_3) \quad (1)
\]

\[
R_3 = \frac{1}{LN} ((L-a)F_1 + (L-b)F_2 + (L-c)F_3) \quad (2)
\]

To account for all possible conditions, the worst case scenario of \( a = b = c = \frac{1}{2} \) was assumed. The weights of the runner stops were found to be \( F_1 = F_2 = F_3 = F = 70 \) lb (311 N). This 70 lbs was calculated using the inertias and dimensions of the strut, found in the Bosch Catalog [1]. Substituting these values into the above equations yields \( R_1 = R_2 = \frac{1}{3}F \). The guide is acting like a simply supported beam. The maximum stress due to bending for a simply supported beam is located at the midpoint. It is found by using the following equation:

\[
\sigma_{max} = \frac{Mc}{I} = \frac{3LFy}{8I} \quad (3)
\]

where the moment \( M \) is found by:

\[
M = \text{force} \times \text{distance} = R \times \frac{1}{2} = \left( \frac{1}{4}F \right) \times \frac{1}{2} = \left( \frac{1}{8} \right)LF \quad (4)
\]

The parameter \( y \) is the distance from neutral axis. 45x45 aluminum strut is the weakest of the available strut profiles, so it was analyzed to account for the worst case. Using the data from the Bosch Catalog [1] and solving Eq. (5) for \( F \) yields a force of 635lb (2823 N). Thus, the weakest of the strut profiles will support the runner stops with ease.

A formula is given in the Bosch Catalog [1] to calculate the life of the Delrin bearings, but the formula essentially concludes that bearing life is inversely proportional to the cost of the EcoSlide. The larger, more expensive slides have more bearings. This puts less strain on each bearing. Thus, the bearing maintenance cost will remain constant; the only cost that changes is the startup cost associated with choosing a slide. The Phenix supplier discount allowed the team to choose the largest slide available for maximum bearing life.

ACTUATION

A.C. Packaging’s shop and tools run on compressed air. As such, it was expressed that the jig should also do so if possible.

As was previously mentioned, Phenix Automation offered the team discounts on a vast array of pneumatic components. Putting these two facts together, the team felt that having their pneumatics distributor right next door was an opportunity not to be wasted, and chose to actuate the jig pneumatically.

In order to choose the pneumatic components, several more free body diagrams were done. Fig. 8 shows the calculations for a cylinder in the center of the runner stop, assuming the previously calculated stop weight of 70 lbs (311 N).

Figure 8: Free Body Diagram For Centrally Loaded Cylinder

Using Newton’s 2nd Law, a simple analysis results in the relation:

\[
P = \mu_s W = .12 \times 70 = 8.4 \text{ lbs (37.4 N)} \quad (5)
\]

Each cylinder must be able to travel \((48” - 20”)/2 = 14”\) (355.6 mm) in order to meet the pallet width specifications. Because of this large stroke, the cylinders will have to be mounted adjacently: in other words, they will be slightly off-centered. The off-centered force will result in a moment, which will grow as the distance off of center increases. Another free body diagram was constructed to account for this.

Figure 9: Free Body Diagram For Off-Centered Cylinder

Generating the problem equations from the diagram is relatively straightforward. They can be combined and solved for the force on the cylinder \( P \) as a function of runner stop weight and distance off center:

\[
Y_1, Y_2, X_1, X_2 \text{ are reactions}
\]

\[
a = \text{distance of slider in direction of linear guide} = 160 \text{ mm}
\]

\[
P = \text{applied force from cylinder}
\]

\[
b = \text{distance of applied force from edge}
\]

\[
d = \text{distance of applied force from center}
\]

\[
L = \text{length of runner stop}
\]

\[
b + d = L/2
\]
Using Eq. (6), an extremely conservative estimate of 2\(\text{"} (50.8 \text{ mm}) \) off of center will require the cylinder to overcome a force of about 10 lbs (45 N). Thus, being axisymmetric is not a problem.

The team found a pair of Allenair 1\(\text{\textfrac{1}{8}}\) (28.575) bore cylinders with 18\(\text{"} (457.2) \) stroke available at a significant price break, and conducted an analysis to determine if they were a good fit for the jig. The standard equation was used to create a graph of cylinder bore vs. required force at various operating pressures:

\[
P = \frac{aw}{2d + a / \mu}
\]

Using the Fluid Power Handbook [2], preliminary calculations were also performed as to cylinder air consumption, required horsepower, and time to extension. These calculations utilized formulas and constants taken directly from this book. It was a valuable reference, and any more information desired about these calculations can be obtained from there. The main cylinders were the limiting factor for the entire pneumatic system; once they were verified by analysis, the rest of the system was chosen with off-the-shelf components from Phenix.

The pneumatic system also has several features designed into it to enhance the robustness and safety of the system. One of such features is a manual override. This is a valve which simply dumps air from the system, allowing it to be used manually during any system down time. An emergency stop is also present to stop the system immediately. The emergency stop is present in spite of the fact that the system operating pressure will be set to 50 psi (344.7 kPa). At this pressure, even pinch points are not dangerous to the users.

**BASE**

The pallet jig base was chosen out of the necessity that the jig be both portable (with two workers, as well as a forklift) and fully self-sufficient (when fed air from the shop). The easiest way to accomplish this was by creating a cart on casters. By doing this, all components and lines could be contained inside the jig. The most logical choice for the base material was Bosch extruded aluminum. This strong, light-weight, normally expensive material was to be taken out of scrap at Phenix for a nominal fee. Its modular design would be ideal for creating component mounts, as well as for future modifications.

The base was designed with the intention of maximizing adaptability and ease of use. The base height is set at 31\(\text{"} (787.4 \text{ mm}) \), the height of their current jig, to maximize ergonomic relief for the workers. It is also dimensionally smaller than the runner stops and linear guide rails. This allows the user to put their feet under the runner stops and stand as close to the pallet being built as possible. Nail gun mounts were also designed into the base to minimize ergonomic strain on the operator. And the front of the base is to be open for storage of nails and other work materials.

A finite element analysis was performed on the structure using the ANSYS package to simulate extreme loading conditions (bump with a forklift, etc.). As expected, the aluminum strut passed all reasonable loading tests.

**THE DESIGNED PALLET JIG**

Figure 11 on the following page shows the solid model of the completed pallet jig. It embodies all of the previously discussed features and subsystems. To use it, the operator simply sets the width pins. The runner stops default to their widest setting and move inward at the push of the CLOSE button. The OPEN button will send the runner stops back out. These buttons are located under the center runner stop on the front of the jig. To operate these buttons, the user is required to push them in and keep them pressed until the jig contacts the limit switches.
Figure 11: Completely Designed Pallet Jig

JIG CONSTRUCTION AND TESTING

The manufacturing of the jig prototype involved some unforeseen problems which led to the altering of the original design. The base construction was quick and easy, but problems arose when the team began integrating the subsystems. A significant portion of the team’s efforts during construction were directed at squaring the jig. If the jig was not square, the pallets would never be. Since everything was based off the center runner stop, it was imperative that it be perpendicular to the frame rails which it mounted on. This took some time but was successfully achieved.

Even more difficult was aligning the strut which served as the linear guide channels. The team learned that EcoSlides are extremely fickle when used synchronously. The carriage channels were aligned meticulously. Smooth, uniform sliding was eventually achieved, but a certain amount of play was inherent in the carriages. The play was such that the runner stop could be cocked up to ¼” (6.4 mm) over its length. The EcoSlide performance was even more diminished when the cylinders were mounted to them. Both the cylinders and the runner stops translated smoothly individually, but when combined the result was choppy. This pulse train movement wreaked havoc on the limit switches. The switches would have to deal with either the high side or the low side of the pulse, depending on where the clamps/pins were set. This irregularity in momentum meant that the time required to halt the runner stop varied greatly. The team could not get repeatable results to within 1” (25.4 mm).

As a result, the limit switches were replaced with positive stops. These stops consisted of a piece of extruded aluminum mounted under each end runner stop, in line with the clamps. The stops impacted a plate on the clamp, which was successfully tested at 60 psi (414 kPa). Despite the hard stops, however, the runner stops were still able to be sloped about 1/8” (3.2 mm). This was finally corrected by installing a second UIS at the rear of the jig. With four hard stops, repeatable results within the specified tolerances were achieved. The necessity of setting four pins was a setback to the team, but the jig would be useless to the sponsor if it was not accurate and repeatable.

The other major hurdle the team had to overcome also involved the runner stop cylinders. Due to the compressibility of air, cylinder creep was present in the system. This was mitigated somewhat by the addition of the hard stops, but the cylinders could still be pushed in towards the center of the jig by hand. A clamping bar was added to keep the runner stops stationary during pallet production. The clamping bar consists of a piece of aluminum strut mounted to two small single-acting cylinders. The cylinders are mounted to the jig underneath the runner stops. When they are activated, the cylinders fire upwards and press into the runner stops, locking them in place.

At some time into production, A.C. Packaging requested that there be one emergency stop on each side of the jig. The emergency stops are also to be kick buttons, located on the bottom of the jig. These changes, as well as the deletion of the limit switches and addition of the clamping cylinders, are highlighted in the final pneumatic schematic shown below.

THE FINISHED PRODUCT

The finished jig successfully integrated all design changes detailed in the previous section. Aside from these changes, the finished product has stayed very true to the original design. T-slot cover strip, end caps, and Alumalite panels have been
Movements done by operator currently | Movements done by operator in new system | Change in number of movements | Percent change
--- | --- | --- | ---
Bending | 16 | 4 | 12 | 75.0%
Reaching | 16 | 5 | 11 | 68.8%
Twisting | 14 | 3 | 11 | 78.6%

A source for linear guide bellows was obtained and recommended to the sponsor. The sponsor declined to add that cost to the jig, but the option is available if the sponsor should reconsider.

**RESULTS**

The completed prototype has been thoroughly tested and has been found to be both accurate and repeatable to within \(\frac{1}{32}\)" (.78 mm). This was the average test result. The greatest inaccuracy obtained on any test never exceeded \(\frac{1}{16}\)" (1.6 mm). Thus, the jig fulfills its obligations on this front.

The main objective of this project was to reduce the jig setup time, and this was not lost on the team. Data was taken for actual jig setup, and the results of the time study are included below.

<table>
<thead>
<tr>
<th>Setup Time (min)</th>
<th>Current Jig</th>
<th>Prototype</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employee Wage ($/hr)</td>
<td>$10.00</td>
<td>$10.00</td>
</tr>
<tr>
<td>Average No. Setups Per Day</td>
<td>4.30</td>
<td>4.30</td>
</tr>
<tr>
<td>Average Cost Per Pallet</td>
<td>$8.53</td>
<td>$8.53</td>
</tr>
<tr>
<td>Lost Revenue Per Setup</td>
<td>$3.73</td>
<td>$0.05</td>
</tr>
<tr>
<td>Lost Revenue Per Day</td>
<td>$16.05</td>
<td>$2.15</td>
</tr>
<tr>
<td>Lost Revenue Per Year</td>
<td>$4,173.87</td>
<td>$559.00</td>
</tr>
</tbody>
</table>

*Annual Savings: $3,614.87*

Thus, the jig has fulfilled its primary goal. It does even better than that, though. *The Automated Pallet Jig cost $1417.50 to manufacture*. By utilizing supplier discounts wisely, the team has built a jig which will pay for itself in 4 months. In addition, an ergonomics study done by the team indicates a significant decrease in the amount of strain put on the operator by the jig.

**REDESIGN**

The fact that A.C. Packaging is a low-budget operation makes any follow-on Senior Design projects unlikely. However, if the opportunity for improvement does present itself in the future, the redesign team should focus on one of these goals:

- Redesign jig such that the operator needs to set only one width pin.
- Redesign jig to incorporate automatic nail guns.

**ACKNOWLEDGEMENTS**

The Automated Pallet Jig team would like to extend sincerest thanks to the project sponsor. Rick and Ryan Rugaber of A.C. Packaging have been involved in all aspects of the project and were a pleasure to work with. Their easy-going, yet committed attitude is what every design team hopes for, and the opportunity to work with them was rewarding.

The team would also like to extend deepest gratitude to Phenix Automation. Special thanks to the owners for their financial and technical assistance, as well as the use of their facilities, tools and machines: John Amrine, Dan Marshall, and Glyn Lipp. The team is grateful to Aaron Cromwell for supplying the team and providing technical support. Thanks go out to Mike Gossen and Ike Lewis for their contributions as well.

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The team would like to thank their coordinator, Dr. Walter. His contributions and meetings helped to keep the team on schedule. His guidance was very much appreciated.

**REFERENCES**