

# Collapsible Pallet

The specification of plastics and their associated technologies in material handling applications has gained continually increased popularity over the past 30 years. The benefits of plastics, which include high strength, light weight, corrosion resistance, and the ability to be cost effectively shaped in any form, have given them a major advantage over conventional materials such as wood or metals. Pallets represent one of the most common and widely produced items within the material handling market. They serve as an extremely efficient means of cost-effectively consolidating many items within a small space which can be easily moved with a forklift. With the advancement of technology, pallets have evolved from simple wood platforms to specialized containers, designed to store and protect its contents within. Market demands for improved efficiency in storage led to the development of the collapsible container, which has traditionally been molded using structural foam polyethylene as shown in Figure 1. The folding nestable side panels are designed to easily unlock from each other and collapse inwardly as shown in Figure 2. This significant feature makes these containers very desirable for warehousing goods since valuable space is efficiently utilized when containers are empty as shown in Figure 3. Since pallets are heavily loaded, stacked, and constantly moved, structural integrity is a critical design consideration. Aside from proper material selection, optimized ribbing is essential for collapsible pallet designs as shown Figure 4.

Although the structural foam molding process has many advantages for cost effectively producing large parts, a decrease in physical properties resulting from the foamed core have been the source of frequent premature breakage problems. Some breakages have been caused by excessive

compressive loads as shown in Figure 5 as well as severe impact failures as shown in Figure 6.

Additionally, breakages shown in Figure 7 can be attributed to poor snap fit design and stress concentrations caused by notched internal corners subjected to high bending moments. Decreased impact strength and higher molded in stresses have also contributed toward premature breakage as shown in Figure 8.

Problems for one manufacturer can become big opportunities for another. Such is the case for Eduardo Duarte Gonzalez, President of Vitrofibras del Sureste, located in Mérida, Yucatán, México who was introduced to me by Carlos Garcia, President of Reduction International. Vitrofibras offers a diverse product line of glass fiber reinforced plastic products ranging from portable waste container bins, guard houses, and trailer storage units to road barriers. After identifying the collapsible container as an immediate business opportunity based on a specific customer's needs, Mr. Gonzalez began developing a rotationally molded replacement which would also compliment his ready board product line. Unfortunately, the design developed by one of his staff was structurally inadequate and improperly designed for rotational molding. The proposed CAD model design shown in Figure 9 on the next page pictorially represented the soon to be replaced structural foam alternative with correct overall size, collapsible side panels, and minimal compressed height. However, the design was flawed with many technical problems including structurally inadequate panel interlocks, omission of kiss-offs, inadequate provisions for tolerance allowances, and generally improper design details required for rotational molding. Luckily Eduardo was forewarned of the potential problems well ahead



Figure 1



Figure 2



Figure 3



Figure 4



Figure 5



Figure 6



Figure 7



Figure 8

of time by the selected tool supplier, Carlos Garcia, who recommended that he contact Integrated Design Systems (IDS - [www.idsys.com](http://www.idsys.com)). After a few conversations between both parties concerning the performance requirements and final deliverables, IDS was contracted to develop the new design.

A summarized overview of the product specifications has been highlighted below. IDS assisted Vitrofibras in defining these performance requirements to account for a variety of environmental conditions as well as basic functional limitations. These included important long term material behavior characteristics specifically related to rotationally molded PE. IDS also noted the importance of specifying material color, loads at elevated temperatures, expansion and contraction, and specification of corrosion resistant hardware.

Darker colors, especially black, absorb heat from the sun at a much greater rate than lighter colors, resulting in increased temperatures, which lower tensile strength and modulus. Heavy static loads at above average temperatures for long periods of time will slowly deform load bearing walls, a phenomenon commonly referred to as creep. Choice of stainless steel, or fiberglass for hardware will resist corrosion versus plated steel which would ultimately rust.

### General Overall Specifications

- Maximum outside dimensions have been defined as 1.25 meters square x 1.237 meters high without lid
- The pallet will include a rotationally molded lid which can be easily removed.
- Interior dimensions have been defined as .95 meters x 1.15 meters x 1.050 meters high
- Minimum acceptable interior Volume = 1.17 cubic meters
- Maximum collapsed height = 38 cm without lid

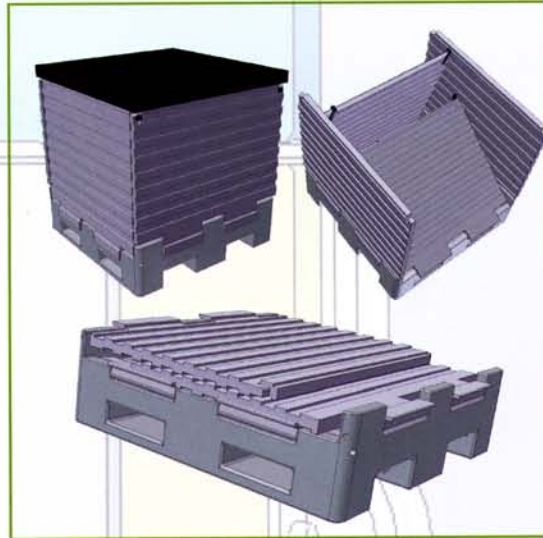


Figure 9

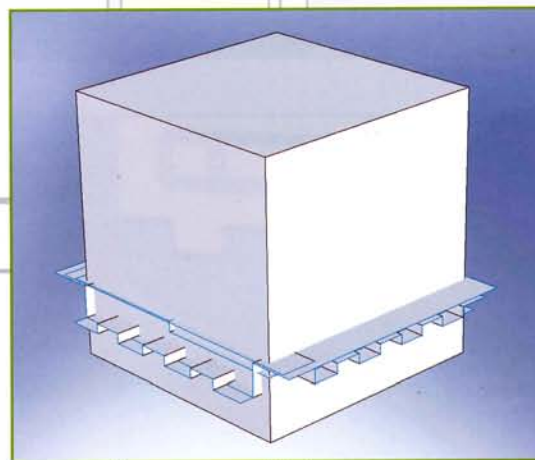


Figure 10

- Bottom collapsed pallet must support a minimum of load of 12 collapsed pallets = 1200 kg and a maximum load of 20 pallets or approximately 2000 kg
- All metal parts must be stainless steel for corrosion resistance
- Pallets must stack with lid

After the specifications were reviewed and finalized, IDS began developing the container design to comply with the physical, functional, and performance requirements previously cited. A master CAD model as shown in Figure 10 was created for the entire assembly, providing complete parametric dimensional control of all the major parts. Individual parts, derived from the master CAD model, were completely detailed in relation to each other to assure proper fit and function. These complex interrelationships required each part to be developed concurrently within a CAD assembly using SolidWorks. The container consisted of three distinct parts including the base, side panels, and top cover. The base was detailed to include tighter than normal clearances typically allowed for rotational molding which is +/- .02in/in as an industry standard. Such a ridiculously wide tolerance range would have resulted in a completely useless product due to excessively large clearances between interacting parts. For example, the clearances between each side panel and base hinge knuckle would have " or 12mm. Maintaining these same clearances throughout the entire pallet assembly would have ultimately resulted in a structure that would be so unstable it would never be able to stack or rigidly stand erect.

Since the molds were to be CNC machined directly from our CAD files using aluminum billets, cumulative tolerances typically associated with patterns and aluminum castings were eliminated. Features for hinging panels, forklift entry ports, kiss-offs, and other functions required by this product were included in the base design as clearly shown in Figure 11 on the following page. The resulting structural integrity of the base was significantly higher than its structural foam counterpart already on the market.

Figure 12 on the next page illustrates four CAD sectional views of the

- Estimated weight= 93.74KG based on a 5 mm wall (includes 13 kg for lid)
- The pallet will be colored light grey

### Structural Requirements

- Pallet must be capable of storing a minimum of 275 kg of preforms, optimum is 320 kg of preforms
- Erect storage pallets will be required to stack to a minimum of 4 high
- Stacked pallets will weigh approximately 400 kg when fully loaded with preforms
- Filled pallets will always be stored in a warehouse with maximum temperature of 30°C
- Collapsed pallets will be stacked without lid to a minimum of 12 high, maximum of 20 high
- Collapsed pallets will be store outdoors with a maximum temperature of 35°C

container assembly depicting numerous design features. Kiss-offs in the base imparted critically needed structural integrity to withstand compressive, torsional, and bending loads encountered during normal use. Two opposing sides of the base included enclosed forklift ports, permitting the pallet to be tipped at steep angles without falling off. The structural foam unit achieved this same feature by utilizing snap locks between the base and a separately molded plate. Excessive stresses typically encountered during normal use, however, resulted in premature failures of this assembly as previously shown in Figure 7. Since Reduction International committed to maintaining tighter than normal tolerances and high mold quality, sophisticated design features normally not achievable with rotational molding were included in the design. These features improved overall performance and product value. One example was the inclusion of a spring loaded panel interlock pin which was recessed and positioned near the top inside wall of two opposing panels for easy worker access. These pins were critical to the foolproof interlocking requirements for erected containers. Tight tolerances also affected the sizes of base pads and nesting top covers when containers were stacked since clearances between these nesting units were restricted by internal as well as external dimensions.

Panel design details were meticulously developed to comply with the numerous functions these parts were required to perform. Figure 13 includes four images of the side panels in various states. The first pictures illustrate a mating hinge detail along the bottom, which was designed to interface with the base using a 10mm fiberglass reinforced rod. The rod opening was designed with sufficient clearance to permit easy insertion through the entire assembly with minimal force until the last block. The remainder of the insertion was a press fit, which locked the rod in place. Long horizontal recesses along the outer surface of each panel imparted rigidity and improved flatness. These recesses also improved air flow and heat transfer to the evenly spaced kiss-offs during molding. Since all panels were required to fold one on top of the other, each was designed individually with its unique set

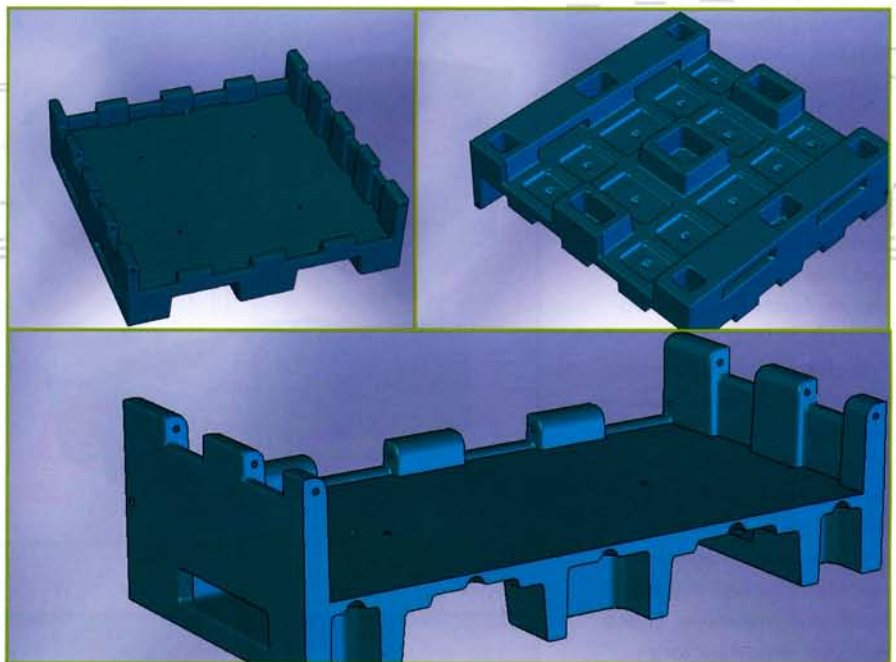


Figure 11

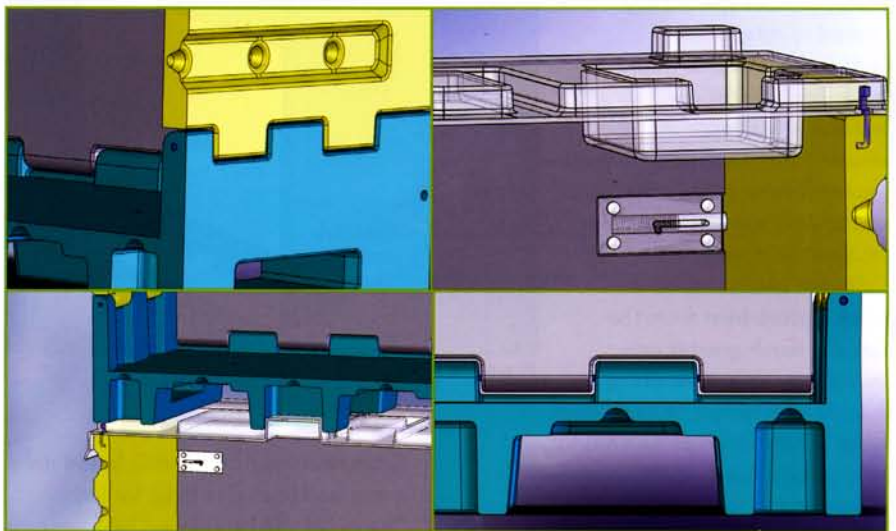


Figure 12

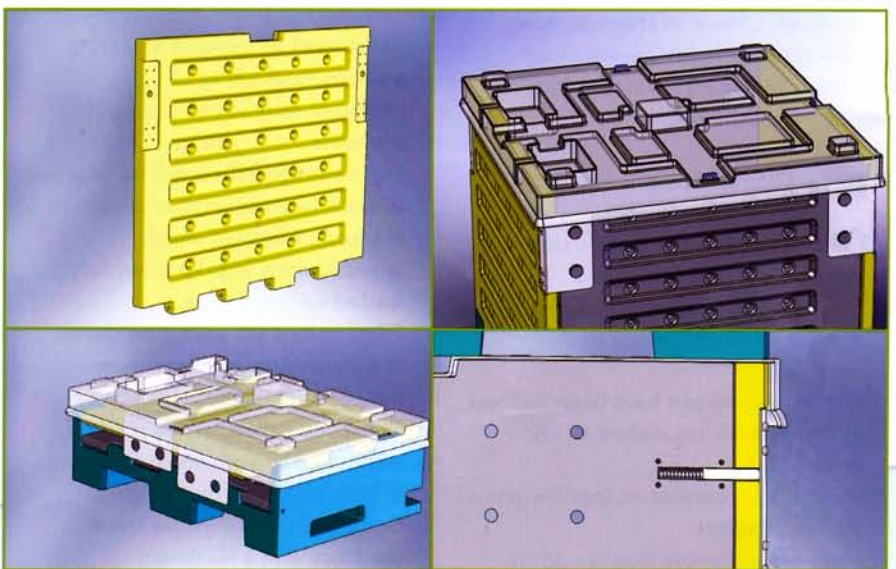


Figure 13

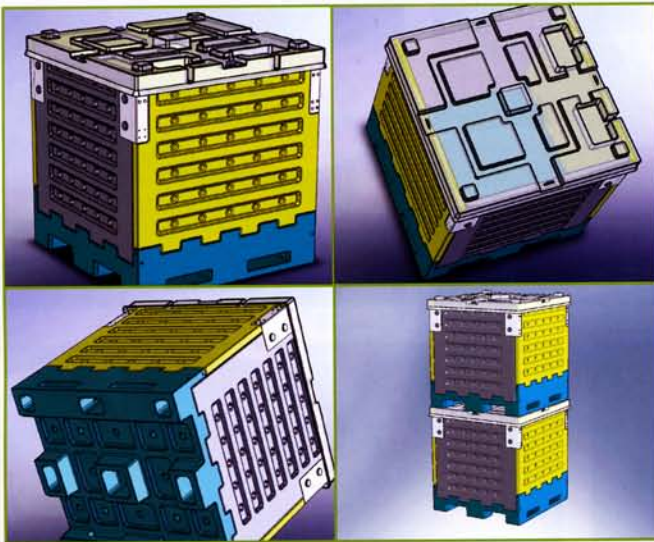


Figure 14

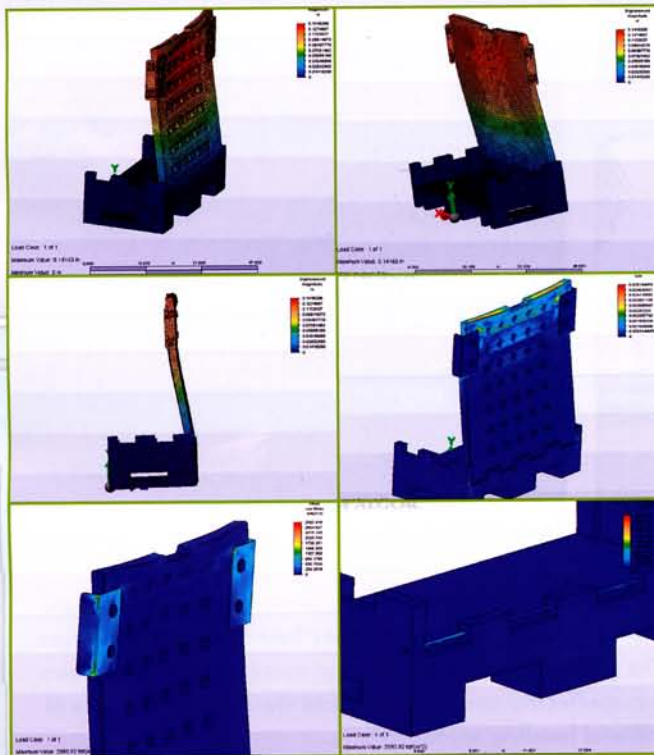


Figure 15



Figure 16

of special features. Opposing perpendicular panels interlocked on both sides in such a way as to prevent unintentional collapse in either direction. As mentioned previously an inner spring loaded pin lock prevented inward collapse while a specially designed "L" shaped corner bracket intersected with two circular features on the opposing panel preventing outward collapse. Placement, spacing, and size of these parts were carefully designed to function in both the erect and collapsed state also shown in Figure 13 on the previous page.

In addition to the folded and erect configurations for this container, the product was designed to stack in either state with a top cover in place. These requirements were restricted by the explicit dimensional constraints specified in the product requirements. Figure 14 clearly shows a standalone assembly of the lid to the container as well as the nesting between the base and top cover in a stacked condition. These sectional details also illustrate the folded side panels within the base and the recessed pad lock tab brackets. These were recessed to prevent accidental shearing or interference when units were stacked.

The final CAD assembly shown in Figure 12 on the previous page clearly shows the pallet design in various views and orientations with the side panels in the erected, interlocked positions. The rotationally molded top cover was designed to be securely placed over the main container using four pad locks in each of the four stainless steel molded in tabs located within each recess. The additional area on either side of each tab recess was provided to include space pad locks. The relatively complex surface of the top cover was designed to interlock with the stacked pallet as well as provide pathways for water to run off, preventing puddles when stored outdoors.

Since prototypes could not cost effectively be fabricated to verify the design, the only means of determining structural performance was the application of finite element analysis (FEA). Figure 15 includes six images of the FEA study which was based on conservative data for PE. The images depict the deflections and stress distributions in the side panels with exaggerated graphical deformations for purposes of clarity since the actual maximum deflections were less than .15". The analysis was only required for one panel since the load was assumed to be uniformly distributed over all four. Stress and deflection results were surprisingly much lower than estimated. After performing this analysis a few times under various conditions, the design was finalized, reviewed with Vitrofibras and released for tooling.

Less than 8 weeks after the files were released, we received photos of the assembled pallet based on first shots from the new tools. The quality, fit, and overall appearance of the product was extremely impressive as shown in Figure 16. Panels were flat, devoid of defects, and they all interlocked as designed. This was a major accomplishment for the tool maker as well as our design team. After Eduardo's official approval, the molds were delivered to his plant in Mexico for production. Being the first rotationally molded product produced at Vitrofibras, it couldn't have been more challenging based on all the critical dimensions and performance criteria. Despite these demands, Eduardo's team successfully began producing high quality pallets shortly after the molds were received. Today, Vitrofibras has manufactured hundreds of pallets with



Figure 17



Figure 18



Figure 19



Figure 20



Figure 21



Figure 22



Figure 21

tremendous success in sales, exceptional performance and customer satisfaction.

Photos in Figure 17 showing the production version of the pallet being transported with a forklift, standing alone and stacked in the collapsed state clearly demonstrate the versatile performance of the product. The actual structural integrity of the container far exceeded its initial expectations of storing 400 kg as demonstrated in Figure 18 depicting a container filled with ice and watermelons. Each pair of enclosed forklift access ports shown in Figure 19 was eliminated in the production unit since it was deemed unnecessary. Tightly maintained tolerances, flatness, and dimensional stability enabled robust molded in hinges to be included at the base of each folding panel as shown in Figure 20. The meticulous attention to design details, which were coordinated with the toolmaker, Reduction International, resulted in a very well engineered container which was far superior to the structural foam competition. Hinged panels securely interlocked when folded upright with a simple yet very strong spring loaded lock pin and outer retaining bracket as shown in the photos in Figure 21. Compact stacking, structural integrity, well designed interlocking features, and precision molding enabled these pallets to be efficiently

stacked in the collapsed state as shown in Figure 22. To date there have been no reports of any field failures or breakages. The rotationally molded pallet has successfully offered users a cost-effective alternative that can stand up to the rigors of material handling applications.

Inherently high impact strength and ductility combined with exceptional design has resulted in a virtually indestructible product that is far superior to its competition. Hopefully, this case study has provided you with another application example demonstrating the versatility of rotational molding. Successful products such as this require a market need, an individual who has the vision to fulfill that need, and a highly skilled design/tooling team to provide the means of realizing that vision. This was a classic design case study for rotational molding since it required extensive knowledge of the process, strength of materials, high level design expertise, and structural analysis. The slightest oversight in any of these areas would have resulted in failure. This container represents a new landmark for the rotational molding process.

For additional information concerning this product design visit [www.idsys.com](http://www.idsys.com).