DESIGN CASE STUDY:

Rotational Molding Versus Alternative Processes

by Michael Paloian, Integrated Design Systems, Inc.

The majority of the public sees products after they have been completely designed,tested and manufactured. They rarely observe the creative process and countless iterations that were required to attain the end result. This is a fascinating process during which creative people must work together using their skills in engineering,art,and science to create new products from an idea. It's not unusual for hundreds of concepts to be created, evaluated,and ultimately discarded. Only those ideas that comply with overall project objectives are selected and refined into the finished product. Often the most interesting concepts are discarded,never to reach the marketplace. This article will take you behind the scenes of a project our firm was commissioned to complete approximately one year ago. This case study will discuss the significance of process and material selection,and its affect on overall design. A discussion of rotational molding design possibilities will be explored and compared to alternative processes such as sheet metal,pressure forming,and casting.

Background

Approximately one year ago my design firm,Integrated Design Systems Inc. was commissioned to redesign a medical device. The product was a neuroaspirator, which was used during brain surgery for the removal of damaged brain tissue. Our objectives were to provide our client with an updated appearance that was versatile,aesthetically appealing,easy to operate, reliable, and cost effective. Front and rear views of the original product are shown in Figs.1a and 1b.

Fig. 1a

Fig. 1b

The original device was manufactured with numerous sheet metal,cast polyurethane,and machined parts that were assembled with hundreds of screws. Covers were assembled to a complex inner sheet metal chassis with elaborate sets of intricate custom made hardware.

The original product was designed tens years earlier by another consulting firm. Although the design had a clean appearance,it was dated,costly to manufacture, difficult to service,and difficult to operate. Our objectives were to eliminate these problems in addition to providing our client with a more versatile higher performance product design within two months.

The project was initiated with a few high energy "brainstorming sessions"to quickly review the existing design,develop a detailed set of design specifications, ideas,and project schedule. Our primary objective was to design a next generation product based on existing components that could be configured to satisfy any of the three configurations listed below:

- The product was to be designed to replace the existing cart as a one-piece portable device that could be easily transported within a hospital.
- A second configuration was required to permit a salesman to easily dismantle the device and place it within the trunk of his car. It would then be required to be easily removed from the trunk and quickly reassembled for demonstration.
- The third configuration required that the same major modules would be suitable for use on a lab bench. In this configuration,the overall height had to be minimal and optimized for desktop height.

In addition to these primary objectives,the new product had to comply with the following specifications:

- Restricted tooling budget
- Limited annual product quantities
- Molded-in color
- Durability and impact strength
- Ease of assembly
- Decreased noise emissions
- EMI Shielding

Analysis and Original Product Critique

Due to the restricted development time,the design team immediately met to discuss the current product based on function,cost,and assembly. These highly energetic meetings provided a rich forum for objectively discussing program objects,problems,and potential solutions for the new product. Shortly after these meetings our design team began dissecting the original product. The unit was disassembled and analyzed based on the following:

- Part name and quantity
- Assembly steps and difficulties
- Components and accessibility
- Hardware requirements
- Function

A brief review of this analysis is described below.

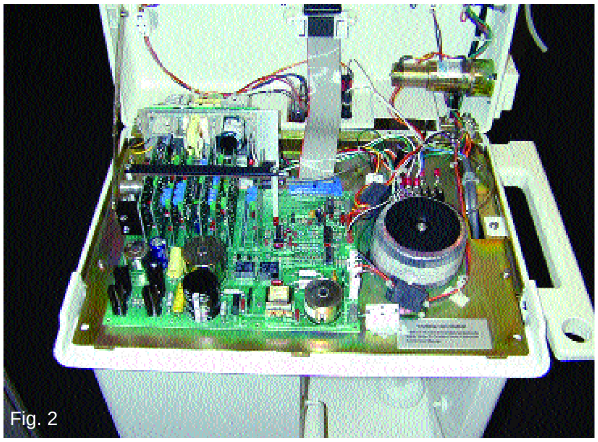

Fig. 2

Fig. 3

The upper section was enclosed in a costly sheet metal/plastic cover assembly. The front control panel was molded in cast polyurethane,which was assembled to a sheet metal top cover. A pair of hinges at the rear provided access to all interior components when the cover was rotated open,shown in Fig.2.

A membrane keypad was located along the front of this assembly for operator interface. Our human factors evaluation of the product confirmed that the keyboard angle was inappropriate for a standing operator and that the angle was too steep as shown in Fig.3.

Fluid pumps that were mounted to the side of this hinged cover complicated the manufacturing assembly process. In addition, a costly cast polyurethane handle assembled to the mid-section of the cart protected the pumps and provided a means of transporting the device.

The compartment at the left was used to store peripheral equipment and supplies while a waste fluid container occupied the right side.

Fig. 4a

Fig. 4b

Both compartments were complicated with hinges,locks and a complex spring loaded retaining bar used to prevent a removable container from falling out.

Figs.4a and 4b show front and rear views of the cast polyurethane front cover. One can readily appreciate the weakened section caused by the thin rib shown in the left photo and the deep pocket shown in the rear view in the right photo. Rigid hand cast polyurethane parts like these are much more expensive and fragile when compared to rotationally molded parts. The black foam shown in the picture on the left was used to dampen sound emitted by a noisy air compressor located in the lower section.

These rear shots illustrate cover details and

Mold in Graphics
P/U
Volume XII Issue 1 Pg. 14

complexities required to wrap the power cord,provide ventilation and electronic output.

A complex and expensive inner steel sheet metal chassis supported these covers and all internal components.

The lower portion of this chassis was insulated with dozens of individual 1"thick sound absorbing foam sheets. Each sheet had to meticulously be adhered to the inner sheet metal chassis. This assembly was further complicated with intricate wire harnesses and tubes running between the lower compartment and the upper control panel. These harnesses were also difficult to install and service.

Early CAD Layouts and Process Selection

Since the new product architecture was based on many of the same components as the original,all internal components were individually photographed. Parts to be used in the new product were then recreated using CAD. During the early stages of design,the components were rearranged in a variety of different assemblies upon which numerous design concepts were developed. These concepts were created using sketches to study a wide variety of aesthetic as well as functional possibilities. During these initial exploratory activities we determined that the new design should be segmented into three sections:

- Upper - which would be an independent subassembly supporting all the electronic components and keyboard.
- Middle - that would provide storage for accessories such as a foot pedal controller and disposable supplies.
- Lower - which contained all the heavy components and mechanical subassemblies such as an air compressor, power supply, and transformer.

Specific manufacturing processes influenced these early concepts. Our objective was to create viable designs that could easily be translated into production units. Concepts were evaluated based on appearance, cost,function,manufacturability, and marketability. Since the forecasted sales were expected to fall between 200 and 700 units per year, our client wanted to limit tooling investment to less than $40,000. Although this restriction was financially prudent,it imposed a serious challenge to the design objectives. The appearance requirements,size of the product,and its complexity had to balanced with low production costs.

This meant that form and function had to be creatively evaluated based on tooling investment,assembly cost, reliability, quality, and total cost. There were only a few viable manufacturing processes that could satisfy these parameters; rotational molding,pressure forming,sheet metal,and extruded aluminum. We immediately began exploring concepts based on each of these alternatives from the beginning since the development schedule was so tight.

The following sections will review the concepts based on rotational molding. Although these concepts were not used in the final product,many creative ideas were developed based on the unique benefits of rotational molding. Hopefully these design considerations can be used by some of you as a point of inspiration for other applications.

Preliminary Concept - One Piece Rotationally Molded Cart

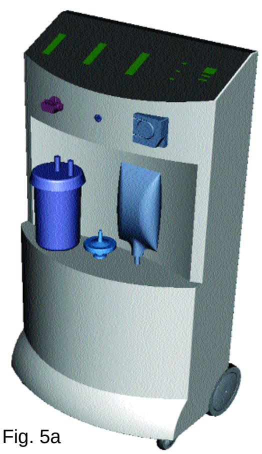

Fig. 5a

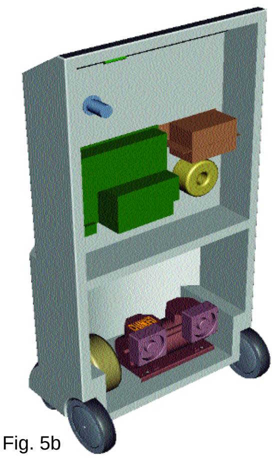

Fig. 5b

The very preliminary concept shown in Figs.5a and 5b illustrates a one-piece rotationally molded medical cart as an alternative to the current complex multipart assembly. This concept had many advantages when compared to the original design. A list of these attributes is shown below:

1. A one-piece molded part would be much less expensive than the complicated sheet metal and plastic assembly of the current product.
2. The proposed double-walled construction would permit aesthetic features to be detailed on the outer walls while complex functional details could be applied to the inner walls. These inner details include mounts for the internal components,wire harness tracks and numerous other functional requirements.
3. Eliminating seams between parts would improve the of cleaning which is so important in medical devices.
4. A single piece assembly would have better structural integrity than a product assembled with many parts and bits of hardware that can loosen or be misaligned.
5. Tolerance buildups would be less critical with a single molded chassis than the current multipart assembly. This would lower costs and improve product quality.
6. Molded in color will eliminate problems associated with painting such as chipping, quality and added cost.
7. Sound absorbing polyurethane or polyethylene foam could fill the inner walls of this structure diminish the noise emitted by the compressor. In addition, foam would contribute toward rigidity and structural integrity.

One of the major drawbacks to this early concept was that two additional molds would have been required to satisfy the other two configurations. Therefore this one-

leonardo

PATENT PENDING

A NEW COMPLETELY AUTOMATIC ROTATIONAL MOULDING MACHINE

Una nuova macchina per stampaggio rotazionale completamente automatica

- LIMITED INVESTMENT
  Investimento contenuto
- AUTOMATIC MOLDING CYCLE: DESIGN AND IMPLEMENTATION BASED ON SPECIFIC CUSTOMER REQUESTS AND DEPENDING OF THE PROPERTIES OF THE ITEM TO BE MOLDED
- COOL AND CLEAN WORKING AREA
  Ambiente di lavoro fresco e pulito
- DIRECT MOLD HEATING/COOLING
  Riscaldamento/raffreddamento diretto sullo stampo
- MANPOWER COSTS REDUCED
  Costi di manodopera ridotti
- THE TEMPERATURE MEASURED INSIDE THE MOLD CONTROLS THE CYCLE
  La temperatura misurata all'interno dello stampo controlla il ciclo
- DIRECT PRODUCTION CYCLE MONITORING FROM THE PC
  Monitoraggio dei cicli di produzione direttamente da PC
- EASY TO USE
  Semplice utilizzo
- REDUCED FLOOR SPACE REQUIRED
  Spazio richiesto ridotto
- MOLD PRODUCTIVITY ON A LEONARDO MACHINE POTENTIALLY EQUALS 4 MOLDS ON A STANDARD MACHINE
  Produttività stampo su macchina Leonardo potenzialmente uguale a 4 stampi su macchina tradizionale
- MOLD CONVERTIBILITY FOR USE ON A STANDARD MACHINE AND VICEVERSA
  Convertibilità dello stampo per utilizzo su macchina tradizionale e viceversa
- REPETITIVE QUALITY IN THE PIECE (NO HUMAN INFLUENCE)
  L'operatore non interviene direttamente sullo stampo: qualità ripetitiva del pezzo
- SAFETY: THE OPERATOR CONTROLS AND MANAGES MOLDING OPERATIONS FROM OUTSIDE THE MACHINE GUARDED BY SURROUNDING PROTECTIONS WITH AN INTERLOCKED GATE
- ABLE TO MOLD SPECIAL MATERIALS (NYLON, PVC, POLYCARBONATE)
  Possibilità di stampare materiali particolari (Nylon, PVC, Policarbonato)
- NO MOLD MAINTENANCE REQUIRED

PERSICO
ROTATIONAL DIVISION

www.persico.com

piece concept was discarded and replaced with an alternative idea described in the following section.

Refined Rotationally Molded Concept

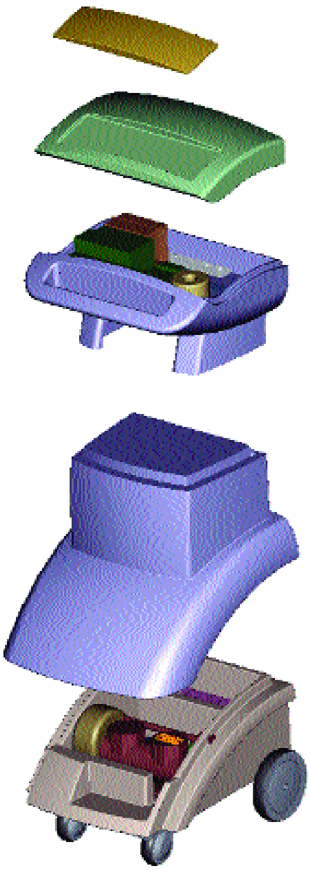

Fig. 8

Fig. 9a

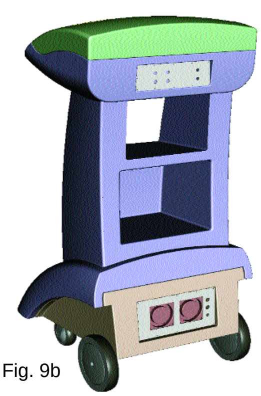

Fig. 9b

Further refinement of concepts based on rotational molding resulted in the more detailed concept shown in Fig.8.

This design concept was sufficiently detailed to a level where mounting features for internal components and structural parameters were included in the proposed design. It clearly demonstrated advantages of rotational molded,serving as a classic example how the versatile the process is. The cart was divided into three sections to satisfy the three configurations required by the client as previously discussed. The following paragraphs will provide you with a more detailed explanation this design.

The base section of this concept was designed with many complex features as illustrated in Fig.9. This portion of the product was required to perform many functions including minimizing noise emissions caused by the air compressor. Baffles were designed as an integral part of the base. The interior of the double walls was to be filled with polyethylene or polyurethane foam to further dampen sound. An interlocking joint between the top cover and base competed this labyrinth of acoustic chambers providing a cost effective baffling system. In addition to minimizing sound emissions, requirements for air intake and exhaust had to be also considered. The open port in the base allowed cool air to be discharged as fans located at the rear of the enclosure. In addition to providing a very effective sound baffle,these walls also contributed to the structural rigidity of the base.

This concept should be contrasted to the original product which was much more complicated and costly. The original product required many assembly man-hours to create sheet metal walled sound baffles and later add sound absorbing insulation. The sound absorbing foam was expensive,difficult to install,delicate,and restricted airflow. Since it contained a layer of lead,the foam also added to product weight,which was to be minimized in the new version.

Molded in inserts located at each boss permitted internal components to be easily mounted from the topside of the base. In the original design,assembly labor was complicated by the fact that the housing had to be continually reoriented as each component was installed. Additional assembly time and complications in serviceability of the product resulted from the original product design layout.

Molded in kiss-offs in the underside of the base added to overall structural integrity. Recesses were also added to the base to provide a location for casters at the front and a wheel/axel assembly at the rear. Counter bored holes were molded in at each screw location to conceal hardware and provide a finished overall appearance.

When appropriate,sheet metal or other processes were specified for the support of certain components. An example of this is the flat panel located at the rear of the base,which supported the fans and electrical I/O connectors. Sheet metal is an excellent material for flat surfaces requiring many holes and thin walls.

It should be noted that the parting line of the base was positioned along a surface that would be buried inside the part. One of the drawbacks of rotational molding is the poor control of parting line cosmetics. When possible,parting lines should be positioned in areas that are not seen or visibly critical to overall cosmetics.

The operator control section in the upper module was

CHEM TREND
P/U VOL. X, ISSUE 6,
PAGE 89.
THE TAG LINE IS "HOUSE CALLS".

also designed with the same objectives as that of the base. A double walled construction yielded a part that would require little to no trimming. Including the handle as an integral part of the upper module provided a unified appearance while minimizing cost. The parting line was designed to fall within the inner section of the handle opening. Although many features were added to the upper module to consolidate parts,details were limited to those features that would not complicate tooling with many undercuts. An exception to this was the rear panel opening,which required molded in inserts and enough detail to warrant a simple loose piece in the mold. The cleanly detailed recess provided a structurally robust rear wall that would also provide a simple way of accepting a low cost sheet metal panel. The recess in the rear provided a clearance space for electrical connectors mounted to the rear panel.

It was decided that specifying a pressure formed top cover would minimize tooling cost yet achieve the aesthetic objectives. A rotationally molded top cover would have been too bulky and diminished overall appearance. The pressure formed cover was to be hooked along the front and screwed to the rotationally molded upper module along the rear.

The hole located at the upper rear corner was designed to serve as a wire and tubing conduit. This channel would be continued within each module providing a means of ducting cables and tubing from the base to the upper module. Wire routing was very awkward and difficult to install in the original design.

Either inserting or omitting the middle section provided our client a means of configuring the device as any of the three products. Actual Final Design

Unfortunately none of these concepts were developed beyond this level. The final design is shown in the picture below: We finalized the production design based on a combination of extruded aluminum,pressure formed Kydex and sheet metal. Our client did not select rotational molding for the final production design because:

- Irregular parting lines on sample parts shown to our client were considered not acceptable.The parting lines were too wide, rough and irregular for a $60,000 medical device.
- The slippery feel of polyethylene was deemed too "toy like"and "cheap"to the touch.
- Surface bubbles located along parting lines were unacceptable and aesthetically unsuitable for an expensive piece of medical equipment.
- Large surface texture features and irregular gloss were unacceptable
- Relatively large radii along edges contributed to the toy like image. Our client was looking for tighter more subtle features that could be achieved with pressure forming.
- The cost of prototyping and verifying more complex rotationally molded prototypes was much more expensive than the selected processes.
- The risk associated with the rotationally molded concepts was much higher than that of pressure forming. This is because features for rotational molding were molded in where as many of the features for the pressure-forming alternative were achieved using sheet metal. Changes are much easier to implement in sheet metal.
- Wider tolerance variations inherent in rotational molding caused concerns about production consistency in assembly and aesthetics.

It is this author's opinion that although some of the concerns raised by our client were valid,many of them could have been resolved. I also believe that designers will continually find new applications for rotational molding. As processing controls and tooling advance improvements will be made in product quality. This in turn will open new market opportunities,as alternative materials become commercially viable. Hopefully this article has provided some of you with some interesting design possibilities for other applications and markets.