PLASTIC PRODUCT DESIGN FOR ECONOMICAL INJECTION MOLDING - Glenn L. Beall

Part 2: In the Beginning

It is difficult to imagine but there was a time when there were no man-made plastic materials and no injection molding process.

The first man-made semi-synthetic plastic was cellulose nitrate (celluloid) discovered by John Wesley Hyatt in 1868. This was followed by Leo H. Baekeland's 1907 invention of phenol-formaldehyde (Bakelite), the first man-made synthetic plastic.

Celluloid was readily colorable. It found wide usage as a substitute material for all kinds of consumer products. Large markets developed for pigmented sheet stock and transparent celluloid in photographic films and cellophane packaging applications.

Bakelite was a stronger thermosetting material with better heat and chemical resistance, but it was only available in dark colors. It became the material of choice for industrial products. This was especially true for applications that could benefit from its good heat and chemical resistance coupled with its excellent electrical insulating capabilities.

The fledgling Plastics Industry continued to grow. Molding processes were refined and a few new plastic materials (notable Nylon in 1931 and Polyethylene in 1942) were introduced, however the growth was modest. That changed abruptly in the early 1940's when World War II created critical shortages of steel, aluminum, copper, rubber, and just about everything else.

That was a terrible war, but it was a golden opportunity for the Plastics Industry. These relatively new materials and molding processes were rushed into production to make up for the shortages. The need was bigger than the industry. Many well meaning technical people, with no formal plastic training, and no experience, were forced into service. Colossal mistakes were made in material selection, design, tooling, and processing. Some of those misapplications made it to the front lines with catastrophic results.

Back in those days if the uninitiated wanted to replace a fabricated sheet steel, or die cast aluminum housing with plastic, they would make a cavity in the same size and shape as the metal housing. They would then discover that they could not fill the cavity. Increasing melt temperature and pressure helped a little. Opening the gate also helped, but they still could not mold a full part. It finally became apparent that the wall thickness of the part would have to be increased for the melt to flow that far.

Once they had a full part they discovered they could not eject the straight sided part off of the core. When they did get a part, it was undersized due to mold shrinking. By this expensive and time consuming process of trial and error, these early Plasticians learned about molding draft angles, corner radiuses, material shrinkage, and the advantages of uniform wall thickness.

By the end of WWII in 1945, there were a significant number of plastics processors who had learned how to use plastic materials to their best advantage. These companies quickly converted from war time to peace time production to take advantage of the pent-up demand for consumer products. Unfortunately, the experienced processors could not keep up with the demand. This created an opportunity for the less, or inexperienced manufactures to start producing plastic products. Many mistakes were made and a lot of shabby plastic products were released into the market. Plastics' war time reputation as a miracle substitute material was suddenly reduced to that of being a cheap, imitation plastic material. Some people still retain that unfavorable impression.

By the early 1950's an actual Plastics Industry was taking shape and expanding. Unfortunately there were not enough technically competent people to take advantage of all of the possible new applications. More inexperienced manufacturers joined the Plastics Industry and contributed their share of low quality products.

The plastic material manufacturers had a financial interest in the success and growth of a Plastics Industry. They concluded that for this industry to reach its full potential, plastics processors needed a better understanding of the technology governing the use of these materials. They were aware that the Universities were not producing plastics engineers or technicians. They finally came to realize that the plastic material manufacturers themselves would have to undertake the gigantic task of educating the plastics processing industry.

All through the 1950's, 60's, and 70's the resin manufacturers visited processors and wrote technical articles for trade magazines, presented technical papers at conferences, and published some of the best technical brochures ever produced. There were brochures explaining all of the different plastic materials, others described how to design mold, or set up and run an injection molding machine, or how to dry material. Simultaneously the same thing was happening with extrusion, thermoforming, blow molding, and all of the other processes.

Most of the material suppliers also published brochures on how to design plastic parts to be molded using their materials. In my career as a product designer these old brochures became bibles. They still enjoy a place of prominence in my library. The brochures covered all of the basics of part design. Over the years those basics have not changed. All that is different now is that we enjoy a better understanding of the basics, and we have the advantage of computer aided engineering.

We owe the plastic material manufacturers a debt of gratitude for their efforts in educating the early Plastics Industry. We must also be thankful for the rich collection of design information that they produced. These old design brochures contain the details that allow the design of parts and products that are ideally proportioned for the combination of the material and the molding process chosen for a given project.

The process of designing a plastic product to be made by injection molding is the same as designing a product for any other manufacturing process or material. Each combination of material and manufacturing method has its own unique design guidelines. However, the product design process itself is independent of the kind of material, or manufacturing method being used.

All new product design projects start the same way. To begin with, someone has to recognize a marketplace need or opportunity. This could be a whole new product, or a line of new products. It can also be a redesign to reduce cost, or improve quality, or eliminate customer complaints. If a new product or a new part is required, a product designer or a design team is assigned to the project.

There are hundreds of interrelated details that combine to produce an injection molded plastic part. All of these details can be divided into four broad categories or elements, which are:

1. The design of the part.
2. The choice of the optimum plastic material.
3. The design and construction of the mold.
4. The actual molding of the part.

There may be additional elements present such as trimming, decorating, assembly, etc. however, the four basic elements will always be present even on something as simple as a poker chip.

All four of these elements must be handled correctly in order to produce the optimum part. All four elements are of equal importance; however everything starts with the design of the part. Without a part design, there is no need for a material, a mold, or a molding process. There is nothing to mold, nothing to sell, and no profit to be made. The only element that is more important than the other three is the one which is not handled correctly.

All the different plastic materials, mold, and processing techniques have their own advantages and disadvantages. A successful part design is the result of the design engineer's awareness of these capabilities and limitations, coupled with meticulous attention to design details. If the design engineer does not have this awareness, it behooves him or her to consult those who have that knowledge. Those consultations are a valuable learning experience for those who are paying attention and who want to learn.

New products are created using many different approaches. No matter what technique is employed, the design engineer should always start by developing a thorough understanding of all of the functional and marketplace requirements of the product. A designer needs to know how and where the product will be used, and by whom. Indoor, outdoor, or both. What is the maximum use temperature? What are the required service life, cost constraints, and quantity to be produced? What is the competition doing in this market area? What regulatory agencies are involved and what will their counterparts required in South America or Europe? Etcetera. The actual process of designing a product must never be started until the designer has learned as much as possible about the application. Once the designer understands what is required, he or she, or the team, are then in a position to design a product that will satisfy that marketplace need or opportunity.

Regrettably some new products are designed without the benefit of a thorough analysis of the marketplace requirement, or trends. IBM's continuing to concentrate on mainframe computers, and the Ford's Edsel are classic examples. In other cases, creative designers have designed what

they personally liked, or what was easy, or what would impress the design competition judges without carefully following the established customer's wishes. While designing product to sell for a profit, the customer is the sole judge and jury. Every effort must be expended to satisfy or exceed the customer's wants, needs and whims.

As the product requirements become defined, they should be recorded. This will create a new product specification sheet or design check list. This list can be used throughout the new product design and development process. It is also a useful communication tool that allows everyone else in the company to sign off on the description of the new product being developed. Marketing people have been known to agree to a new product's specification and then change their mind about what a new product should be. The list won't prevent that from happening, but it will place the blame where it belongs.

Once the design engineer has a clear understanding of the functional requirements of the product in the hands of the end user, the actual design process can begin. The first step is for the designer to simply think about what is required and how to achieve it. This is the critical time, when prior knowledge of the marketplace, past experience, and education become so terribly important. This leisurely appearing activity is actually very intense. This part of the process should not be rushed. The decisions made at this time will determine the course of the project from that point on. This is especially important work. The company will eventually choose one of the designer's concepts to take to the market. The company's financial success and the designer's reputation, and maybe his or her job, will be determined by the marketplace success or failure of the product.

Creative designers have the ability to see things that do not exist. As a designer thinks or daydreams about the new product, random ideas, possibilities, and recollections of prior successes and failures will begin to come together to form a mental image or picture. The designer then begins to record these mental pictures so that others can see what he sees in his mind's eye. This takes the form of doodling, then sketching, and maybe renderings. What the designer is actually doing is experimenting with different shapes in sketch form, looking for a physical structure that will satisfy the functional requirements of the product. This trial and error process continues until the designer has evolved one or more structures that he feels comfortable in being able to develop into a commercially successful product.

Today everyone is in a hurry. Many new products fail because a company proceeds with the first concept that appears to be acceptable without waiting for the best concept which will be evolved later, after the designer has had a longer time to think about the product. The creative process takes time and it is unwise to rush this critical phase of a project.

As the shape of the new product emerges, the designer will simultaneously be thinking about a lot of other details, such as what would be the best process for producing this shape, in what material. The inherently lower cost tooling and quicker delivery of thermoforming will be mentally compared to injection molding's lower part cost and ability to produce precision dimensions, but at a higher mold cost. These preliminary choices in process and material will immediately influence how the designer sketches the product from that point on. Injection molded parts are not designed the same as thermoforming parts.

A host of other details will be passing through the designer's mind, while the new product possibilities are being sketched. Where will the product be assembled and by whom? The appearance of the product, mold design, cost, delivery, decorating, packaging, etc. The designer will also be considering the standards established by such organizations as the Food & Drug Administration, Consumer Product Safety Commission, Underwriters Laboratories, the Federal Trade Commission, etc. In other words, everything having to do with the product is being considered during the design concept phase of the project.

Before proceeding any further with the project, it is desirable to review the concept with an industrial designer. Industrial design is different from engineering design. In recent years, the industrial design function has expanded to encompass many aspects of plastic product design. Two of those functions that are important to the success of many new products are appearance design, and human engineering. Human engineering has to do with proportioning a product so that it fits people and can be conveniently used by human beings. Is the height of the chair seat usable by both adults and children? Does it have to be?

The size, shape, color, surface finish, and the way light reflects off of a consumer product sitting on a store shelf is what first attracts a potential customer's attention. The appearance of an industrial product may not seem to be as important of a consideration. That is an incorrect assumption. Raymond Loewy, one of the founders of the North American industrial design profession, correctly observed that, "Between two products, equal in price, function, and quality, the better-looking one will outsell the other."

Industrial designers receive special training in appearance design, human engineering, and many other subjects. The early input of a qualified industrial designer can greatly increase the customer's acceptance of a product. It is beyond the scope of this article to do justice to the industrial design function. However, industrial designers are another valuable resource that design engineers are not using to it full advantage.

It is important to recognize that during this part of the project, the design engineer is considering and making instant trade-off decisions on a large number of details. It is easy for the designer to overlook one of these details. At this phase of the project, the designer must concentrate on satisfying all of the product's functional requirements. At this point, customer acceptance takes priority over efficient manufacturing.

The best of these sketches is then cleaned up and reviewed with the Marketing Department and other concerned parties. Theoretically, the Marketing Department knows what the customer wants. Marketing will review the design checklist, or product specifications. They will also study the concept sketches or renderings, and make a decision as to whether or not the designer has created a structure that will satisfy the customer's expectations. If the proposed designs are not acceptable, the designer will be sent, as they say, "back to the board" to try again. If Marketing approves of the structure shown in the sketches, the new product will move onto the next part of the design process.

The Marketing Department has important functions to perform, but designing new products is not one of them. Most experienced marketing people realize that creating a new product concept is important work and they tend to allow time for this phase of the project. Never having developed a product themselves, they tend to believe the work done between concept approval and market introduction is just routine engineering. This is not true, but this is what Marketing chooses to believe.

Once the Marketing Department sees a sketch that looks like it will do what they want it to do, they are understandably in a hurry to get the product into the marketplace at the earliest possible date. From that point on, the product will be on the "fast track". There will no longer be time enough for the designer to sit back and contemplate improving the product beyond its present state.

It is important to recognize that once the Marketing Department approves one of the new product concepts, that design tends to be locked in. The designer has then lost the freedom to alter the design without securing Marketing's agreement. This means that if the designer does not incorporate ease of manufacturing into the original product sketches, the single best opportunity to do so will be lost forever. Studies by the Institute of Competitive Design have indicated that the decisions made up to this point will determine 75% of the product's cost.

As the product works its way toward production, more and more people will become involved and it will become increasingly difficult to change the original design. This is especially true when the project is handled by simultaneous or "concurrent engineering".

Many injection molders have been producing commercially successful plastic products since the Second World War. These experienced molders are very knowledgeable concerning the tricks of the trade for producing plastic parts. In most instances they know more than their customers about molding high quality, low cost plastic parts. It is highly desirable to invite an experienced molder to critique the manufacturability of a new plastic product before proceeding with the project.

Considering this brief review of the first phases of the new product development cycle, it is obvious that in order to significantly influence the product design, an injection molder has to be in contact with the product designer before the original design concepts are submitted for Marketing's approval. The early supplier involvement program is a proven method of keeping an open line of communication between a designer and an injection molder. This procedure will allow a molder to make efficiency improvement suggestions before new product design concepts are approved and locked in by Marketing. Electronic data transfer and on-line communications have now simplified the early supplier involvement to the point that there is no longer any credible excuse for not taking advantage of this free resource.

Part Three in this series will address the important but frequently overlooked difference between product design and part design.