Introduction to Scientific Processing for Injection Molding

Injection molding is one of the most common techniques employed in the manufacture of plastic products. Injection molding of plastics began as an idea by the Hyatt brother for the manufacture of billiard balls in the late 1800s and has evolved to a much complex operation in recent years. This evolution is being driven by a variety of forces. The need for complex parts with tighter tolerances, the types of materials, the implementation statistical quality concepts have all been some of the driving factors for this advance. Although the basic process of injection molding has remained the same, over the last couple decades the application of certain scientific principles has led to a better understanding of the process. This understanding has helped to make the processes robust, predictable and efficient.

The actual injection molding process has been traditionally defined as the inputs to the molding machine. Injection speeds, pressures, temperatures and times are examples of these and are recorded on what is called a Process Sheet. However, the word process now needs to be redefined as the complete operation that encompasses all the activities the plastic is subjected to, inside a molding facility – form when the plastic enters the molding facility as a pellet to when it leaves the facility as a molded part. For example, the storage is the plastic, the control of the drying of the plastic and the post mold shrinkage of the part can have a significant influence on the quality of the part. To control the quality of the part, every stage must be understood. Molding a part that meets the quality requirements is easy but molding parts consistently is the real challenge.

<u>Process Robustness and Consistency:</u> The aim of developing a molding process should be to develop robust processes that would not need any process modifications once the processes are set. Process consistency leads to quality consistency. There are three types of consistencies, cavity to cavity consistency, shot to shot consistency and run to run consistency. Cavity to cavity consistency is required in multicavity molds so that each cavity is of the same quality of the other. Shot to shot would mean that every consecutive shot would be identical to the previous shot, or the first shot is identical to the last shot of the production run with the process parameters having remained the same during the entire run. When the process parameters from two different runs were identical and they produced the same quality parts, then this is called run to run consistency. Robust and stable processes always yield parts with consistent quality with one established process.

Scientific Processing: Scientific Processing is the process of achieving consistency in part quality via the application of the underlying scientific principles that control the parameters of the molding process. The goal of scientific processing should be to achieve a robust process. Figure 1 shows the journey of the pellet through an injection molding facility.

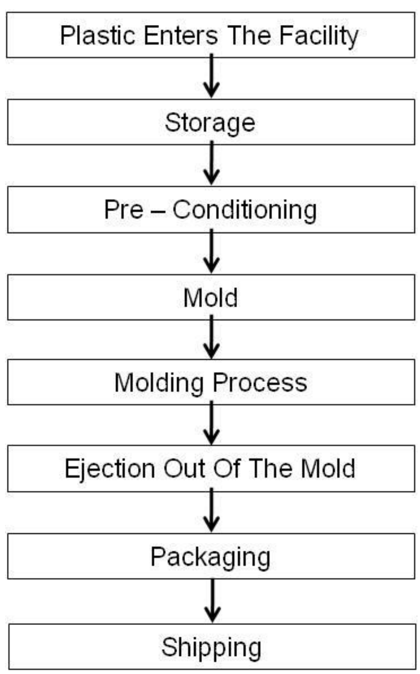

Figure 1: The journey of the pellet and the critical factors that need to be controlled

Scientific processing deals with finding the robust areas of each of these sub-processes. For example, plastic should be dried as per the recommendations of the manufacturer but also must never be exposed to excessive drying time. Research has shown that there can be loss of properties and processing inconsistencies with over dried resin.

The molding process consists of the injection phase, pack and hold and the cooling phase. In-mold rheology(Fig 2) helps in optimizing the injection speeds. A pressure drop study (Fig 3) determines if there is enough pressure to move the screw at the set velocity and that the process is not pressure limited. A cavity balance study (Fig 4) helps is determining if the cavities fill evenly and if cavity to cavity consistency can be achieved. A process window (Fig 5) helps in optimizing the pack and hold pressures. A gate seal test (Fig 6) helps in optimizing the gate seal time and a cooling study (Fig 6) helps in optimizing the cooling time.

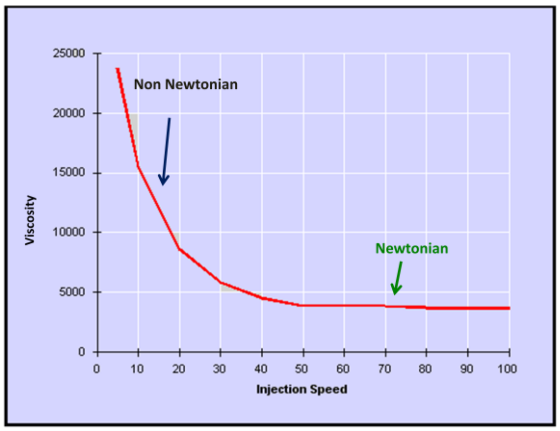

Figure 2: In-mold rheology curve showing the non Newtonian and Newtonian region

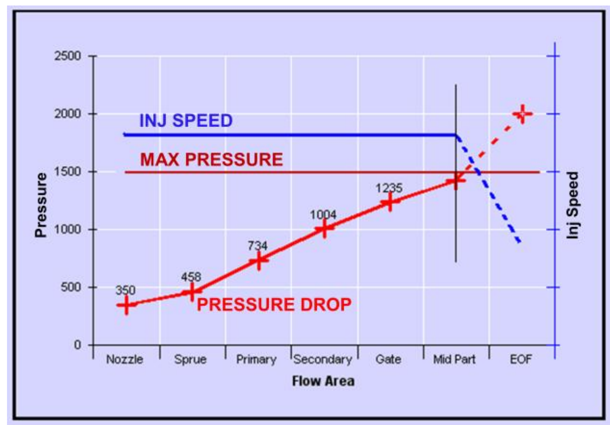

Figure 3: Pressure Drop Study

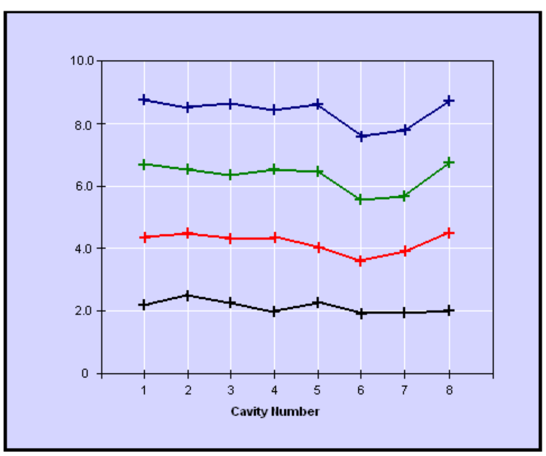

Figure 4: Cavity Balance Graph

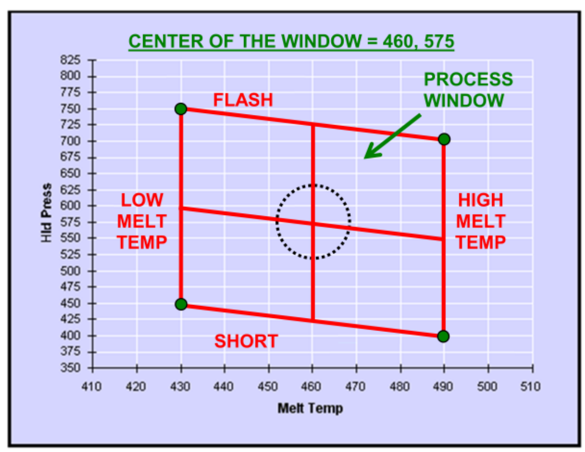

Figure 5: Process Window Study

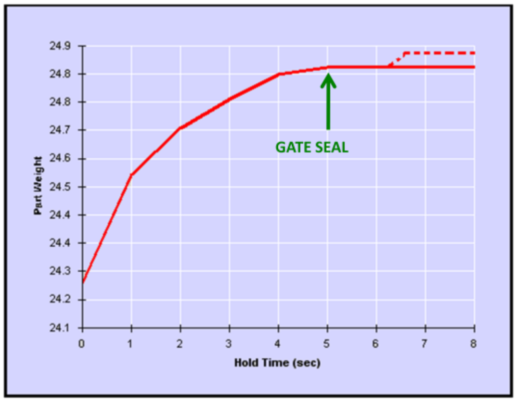

Figure 6: Gate Seal Study

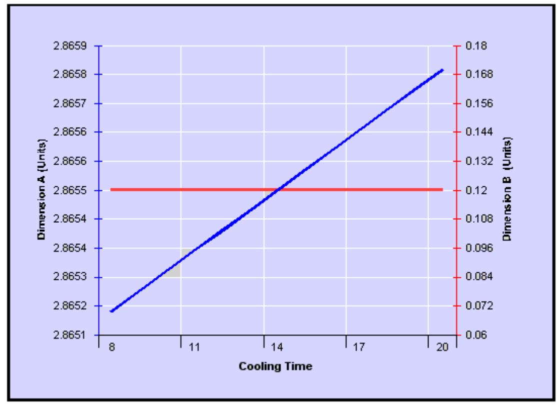

Figure 7: Cooling Study Graph

Once the above studies are done, a designed experiment (DOE) is performed to find the dimensional process windows that give an indication of how well can the process be centered to achieve robustness (Figure 8). Finally a post mold shrinkage study (Fig 9) gives the information about the shrinkage that takes place after the part is ejected out of the mold. This is done at an established process and therefore be done last. Establishing a process based on these studies leads to a robust and consistent process.

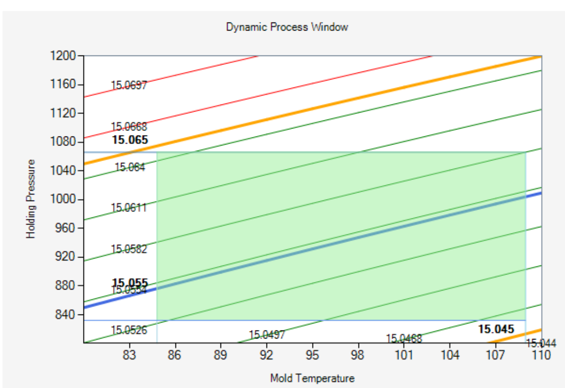

Figure 8: Dimensional Process Window

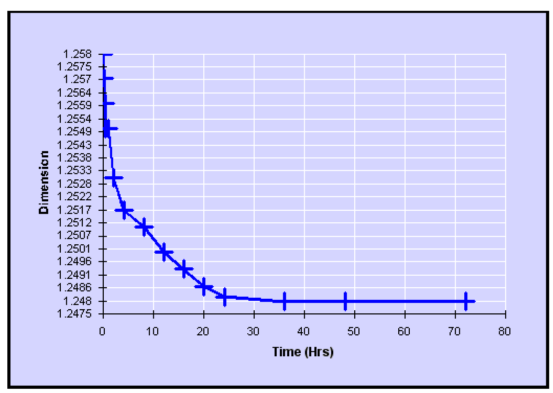

Figure 9: Post Mold Shrinkage Study

Performing these studies also helps in pinpointing the issues with not being able to produce a robust process. For example, a small process window will point to poor mold construction or shot to shot inconsistency may point to a wrong choice of the molding machine. There are five critical factors to a successful molding operation as were discussed in a previous article. They are part design, material selection, mold design and construction, the molding machine selection, and the molding process. Each of these factors plays a very important role in the production of the molded part and therefore each of these have to be optimized for producing the mold part.

With today's truly global market, the competition in the manufacturing sector has never been more aggressive. Profit margins can be lost in an instant if a lot of manufactured product was molded out of specifications. The need for predictable and consistent quality dictates the need for robust processes. Scientific processing is a systematic tool to achieve such as goal.