INNOVATIVE FOAMING TECHNOLOGIES

Blowing Agents and Foaming Processes 2002
Heidelberg, Germany

By
Michael E. Reedy, President
Reedy International Corporation

INTRODUCTION

Many new innovative technologies are now being introduced and re-introduced for foamed injection molding processing. Often called microcellular foaming, the new technologies utilize a number of approaches to achieve fine cellular structures with double-digit weight and cycle time reductions. The key to the innovative technologies is computerized process control, good tool design including counter pressure, static melt mixing and new chemical blowing agents. These technologies have subtle differences, which are very important for optimum part performance.

Technologies include a microcellular injection molding process using supercritical gas and polymer mixtures, which reduce part weight while creating a swirled surface finish. A Class A surface is obtained with the use of Textron's IntelliMold technology, which is a process control system that decreases part weight and cycle time while eliminating surface irregularities.

In addition, new compact gas counter pressure (CCP) modules are providing significantly improved structural foam processing. Processors are also using new tailored static mixers to create highly uniform melt components at constant temperatures.

New chemical blowing agents (CBA) are making dramatic strides in achieving reproducible cell distributions and cell size in microcellular foaming. New applications include automotive moldings such as foamed bumpers and fascia. Chemical blowing agents now utilize microencapsulated small particle size components with very narrow distributions to achieve both significant weight reduction and cycle time improvement. Trials have shown these improvements can be achieved on conventional equipment.

INJECTION MOLDING (IM) FOAMING

A new study on polymeric foams shows a worldwide market of about 15 billion pounds, with a U.S. market estimated at 7.4 billion pounds and growing at about 3% percent per year. Foamed injection molding applications are a growing portion of this market because of a number of innovative foaming technologies and processes. Most commercial foams are considered microcellular because of the very fine and uniformly distributed cells in the polymer. The use of foams reduces resin consumption while producing products with excellent physical properties at reduced product densities. In addition, endothermic chemical blowing agents will allow for reduced processing temperatures, injection pressures and clamp tonnage. Often a key cost benefit; chemical blowing agents reduce cycle time to give foamed processes a real cost benefit.

FOAMING PROCESSES

Key foaming processes include straight injection molding low/high pressure SFM, gas counter pressure, gas co-injection molding, gas assist molding, chemical gas assist and the new Intellimold Process. Low-pressure structural foam injection molding is sometimes referred to as the Union Carbide Process and was patented in 1966 by Angell. Low-pressure structural foam mold or "Think Big", as Steve Ham likes to characterize it, was an early commercial success because of inherent economic benefits. The reduced stress of low-pressure molding also provided greater functionality. There are many adaptations of the injection molding process, including single or multiple gates and advanced methods such as co-injection, expanding molds, or counterpressure. These variations all have in common the addition of a blowing agent, which expands at some point in the process. Typically this expansion compensates for resin shrinkage with an internal cushion of expanding foam verses solid molding where the mold is packed with high resin injection pressure. The result is lower more evenly distributed stress giving the capability for tighter tolerances in larger parts.

Gas counterpressure structural foam processing was developed over 20 years ago. A paper presented by Michael Caropreso at an SPI conference provided a check list of advantages, such as improved surface appearance, cost savings, weight reduction and reduced out gassing times. Most often increased tool complexity is not required but low-cost auxiliary equipment may be necessary. Caropreso's paper focused on clamp tonnage requirements, gas/ flow management and tooling modifications, including mold sealing techniques.

Evidence of the use of Gas Assist Injection Molding Process (GAM) dates back to the early 1970's. It reached commercial success in the 1980's. The use of high-pressure inert gas in conjunction with conventional injection molding, allowed resin to be displaced. The process involved the mold being partially filled with plastic resin and the introduction of gas completed the fill of the tool cavity. Essentially, parts were hollowed out with gas channels to reduce resin usage, lower cycle times, reduce clamp tonnage and improve cooling cycle times.

One of the newest processes in injection molding is called Intellimold™. Intellimold received the Plastic News nomination for "Processor of the Year". This process brings real-time, automated closed-loop control to the molding process. Intellimold provides even greater improvements in physical and dimensional quality.

Microcellular foam molding process and molded products involves a set of licensed technology and equipment modifications. Trexel offers turnkey process development and provides application-support packages. This increases foam process development. Results have shown that end-users have experienced improved cell size reductions along with weight and cycle time improvements.

Michaeli Sasan Habibi-NAINI-IKU of Aachem, Germany; Dr. Minor Shimbo-KANAZAWA INSTITUTE OF TECHNOLOGY, Japan; Peter Clark-CORALFOAM Ltd, U.K.; and Ergocell, Demag Ergotech, Strongville, Ohio, offer other major microcellular foam licenses. All of these license technologies have re-energized the interest in structural foam and stimulated foam process development. Processors are able to achieve improved cell size reductions with good distribution. This produces double-digit weight and cycle time improvements.

ROLL OF CELLULAR STRUCTURES

The nature of cellular architecture involves appearance, wall thickness, cell dimensions and distributions. High-density foams typically have regular, spherical cells near the center and elliptical and elongated cells near the surface. Relatively uniformly thick membranes characterize low-density foams from polystyrene or polyethylene. The most important consideration, however, is that foam density is the dominant characteristic that influences foam strength.

Foam properties are usually directly related to properties of the polymer in an unfoamed state. Foam density reduction results in reduced mechanical properties such as flexural, compressive, fatigue, impact and tensile strength. Although changes in cell architecture such as cell shape, size and distribution can affect mechanical properties; the effects are secondary when compared to density.

Important physical properties are tested at short- term, moderate and long-term intervals. The important moderate terms include the familiar tensile and flexural modulus and elongation at break. In the short term, critical properties are dart drop impact and tensile impact strength. For the longer term, key mechanical tests are fatigue strength, creep and stress relaxation.

ROLE OF ENDOTHERMIC CBA'S

Our chemical blowing agents or CBA'S are microencapsulated, finely milled powders. The encapsulant materials are unique polymeric surfactants which work to improve emulsification and solubility in the polymer melt. The endothermic powders are masterbatched or pelletized with carrier resins that provide improved impact strength, surface appearance and physical properties in selected polymer families.

We know from many studies that the active ingredients, particle sizes, and their distribution affect the cell size of the foam structures. Typically, finer particles, usually milled, with narrow size distributions, will create the finest cells. Surfactants tend to increase the distribution of the particles within the polymer matrix and increase the number of very fine, regular cells formed.

Studies have also shown that microcellular foams can be easily created with CBA's without expensive high-pressure pumps and controllers, complex metering stands or extruder modifications such as special screws. Although screw design is important for good foam, the worst designs for foam are the barrier screws.

MICROCELLULAR FOAM PROCESSES

Microcellular injection molding is characterized by a fine cellular structure between 7 μm and 100 μm. Studies at the University of Massachusetts found that the presence of low molecular weight impurities (parts/millions) in polystyrene will dramatically affect cell size. Our analysis shows that small amounts of impurities or residue from surfactants flame retardants, colorants, stabilizers etc. can be either beneficial or detrimental to controlling polymeric cell size.

The key concept is that super critical gases are produced from either a chemical blowing agent or injected gases such as CO_2, N_2 or various hydrocarbons. When the pressure in the barrel is sufficiently high, the gases enter a new state of matter called a super critical fluid. As an example, CO_2 will become a super critical fluid in most polymers at 1,100 psi (75 bar), which will drop the processing temperature by 50º C. In typical IM processes, given good distribution of the CO_2 in the polymer, a reduction of 10º F to 40º F in processing temperatures can be expected.

Microcellular foam parts have reduced internal stress. CO_2 in the polymer at low pressure will act as a lubricant, helping the polymer chains slide over each other. This promotes part filling, lowers internal stress and reduces stress cracking. Surface features such as skin vs. non-skin and splay are easily controlled by accurate control of the injection molding process. Tools in the processor's kit include adjusting the injection speed, gate size, venting, tool temperature, melt temperature and gas pressure inside the tool.

INTELLIMOLD PROCESS

Intellimold is a real-time process control method for injection molding that uses a pre-pressurized cavity and controls material flow, creating a new process parameter called Internal Melt Pressure (IMP). By controlling the IMP of the material throughout the injection molding process, consistent part density is maintained. Intellimold calculates the IMP by accounting for molding performance variables such as flow rate, melt temperature, modulus, shrinkage factors, part configuration and internal stress levels. Key features of the Intellimold include a pre-pressurized cavity using a pneumatic system and controlled material control. Transducers are placed at the injection nozzle and inside the mold cavity at the last place to fill.

As the melt is injected the transducers feed temperature and pressure data to a controller. The controller then adjusts the injection velocity and maintains a constant IMP. This allows the automatic process to overcome the shrinkage forces and air resistance inside the cavity. The result is that part quality is controlled automatically rather than through experimentation.

Consistent internal pressure eliminates rough surfaces and other irregularities common to existing microcellular processes, such as the MuCell system. The closed loop control system with transducers and microprocessors is sophisticated and very effective.

SULZER MELT HOMOGENIZATION

High quality injection molding can only be achieved with a consistent, highly homogenous resin melt. Sulzer mixers are being used in most IM processes from straight injection to Intellimold and high-pressure injection systems. Studies have demonstrated that Sulzer mixers provide a low-pressure drop and low shear forces result in a significant improvement of polymer behavior.

Sulzer’s mixing elements are produced from corrugated plates, forming open, intersecting channels. This results in two large volume counter-rotating eddies which create an ideal cross-flow pattern. This approach to mixing yields an even distribution of temperature and additives. Constant melt viscosity and temperature allows formation of a very fine and uniformly distributed microcells.

A recent study was conducted on the role of endothermic foaming agents and supercritical CO_2. In a series of trials, foaming agents and polypropylene homopolymers were homogenized with a Sulzer mixer by being folded thousands of times without shear heat or pressure drop. The trials demonstrated improved control of the foaming process both in terms of melt temperature and dispersion at the nozzle. A highly homogenous melt creates a fine, microcellular foam throughout the mold. Surfaces approaching Class A were also accomplished utilizing gas counter-pressure techniques. The molding trials achieved target weight reductions in thin-wall configurations along with improved cycle times and reduced machine energy.

CAROPRESO CP CONTROL MODULE

In addition, new compact gas counterpressure (CCP) modules are providing significantly improved structural foam processing. Developed primarily as a surface enhancement technology, gas counterpressure is a time-tested injection molding process that requires no licensing or royalty fees. Counterpressure provides a controlled resistance to the flow front and helps eliminate surface imperfections such as color streaks, blisters, splay or fibers. It also leaves a smooth injection quality surface.

The only costs for the process are for the tooling modifications and the control module. Gas counterpressure involves simple modifications to standard injection molding machines. Molds are modified to accept a parting line seal. Depending on complexity, slides, cores, ejector pins and other areas must also be sealed. The molding sequence involves compressing the seal and pressurizing the cavity, injecting the resin into the pressurized cavity and then controlling the venting to optimize filling. After injection, the counterpressure is vented into the atmosphere; the polymer cures and parts are ejected.

CONCLUSION

As we have discussed, there are a number of new technologies for producing injection molding foam applications. Consideration must be given to polymer selection, process parameters, extrusion processing equipment and chemical blowing agents. Experience has shown that no one set of equipment, or process modifications or special additives will solve all problems.

The microprocessor controllers melt mixers, foaming agents and compact gas counterpressure units all offer benefits. We believe a careful review of these costs and benefits of the new processes will allow the processor to be a part of the future of plastics processing

REFERENCES

Aedeji, Adeyinka, Use of Blowing Agents to Improve Processing of Engineering Plastics, Proceeding, Foamplas '97

Caropreso, Michael H., *Technology Advancements in Counterpressure Structural Foam Processing,* Proceedings from 14th Annual Structural Foam Conference, 1986

Eichiseder, Martin, *Injection Compression for Excellent Microstructure Molding,* Proceedings from K-PLAST 2001 Foam Conference, Dusseldorf, 2001

Guergov, Milko, Method *and Control System for Injection Molding in Pre-Pressured Cavity,* Proceedings from 25th Annual Structural Foam Conference, 1997

Ham, Steve, Low *Pressure Structural Foam-The Next Millennium,* Proceedings from 27th Annual Structural Foam Conference, 1999

Hilyard, N.C. and Cunningham, A. *Low Density Cellular Plastics-Physical Basis of Behavior,* Chapman and Hall, New York, 1994.

Klempner D, Handbook of Polymeric Foams, Oxford Press, New York NY 1982

Maurer, Rudolph *Study Into the Use of Static Injection Blender on Injection Molding Machines to Improve the Mixing Efficiency of the System,* Proceedings from 27th Annual Structural Foam Conference, 1999

Pierick, David, M*ucell Microcellular Foam Molding Technology,* Proceedings from 27th Annual Structural Foam Conference, 1999

Reedy, Michael, *Chemical Foaming Agents Improve Performance and Productivity,* Proceedings from 27th Annual Structural Foam Conference, 1999

Throne, Dr. James L, *Thermoplastic Foams,* Sherwood Technologies, Hinckley, OH 1996