TECHNOLOGY ADVANCEMENTS IN COUNTERPRESSURE STRUCTURAL FOAM PROCESSING

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INTRODUCTION

General Electric Plastics is continuing to make strides toward better understanding and refining the process of gas counterpressure used to mold engineering structural foam parts.

A revolutionary process, gas counterpressure (CP) evolved from the low pressure foam molding process. The CP process is best known for enhancing the aesthetics of structural foam molded parts, since during the process, parts gain smooth injection-quality surface. Simultaneously, the process offers the molder and end user many additional design, engineering, and processing benefits, including greater functional design freedom and better dimensional consistency. It offers added engineering freedom because a couterpressure molded part has uniform cell structure, improving the part's overall mechanical properties. Processing benefits include the ability to produce parts with no cycle time penalty. CP molded parts can, for the most part, be molded on existing equipment or machinery to which relatively low cost auxiliary equipment has been added. Fewer rejects usually result from the process and cost savings are realized through reduced secondary operations finishing.

DISCUSSION

The intent of this discussion about counterpressure foam processing is to inform the structural foam community of benefits, but as importantly, to educate the community on: (a) the specific network/circuitry that enables the process to work; (b) necessary tooling modifications to existing tools or specific requirements to examine in selecting new tooling; and lastly, (c) circuitry/network sequence adjustments and the effects of various sequence adjustments on the finished CP foamed part.

THE GAS COUNTERPRESSURE PROCESS

The CP process is seemingly technical in nature, but can be easily understood when broken down into the basic function it performs.

The counterpressure process works like this: molten polymer is shot into a gas pressurized mold. Internal inert gas blowing medium is prevented from breaking through the surface polymer melt during processing, and a solid outer skin forms as the foamed cellular core expands during controlled venting. Gas counterpressure equalizes pressure on molten polymer flow throughout the mold cavity.

The normal foam molding process creates uneven cell structure, but the uniform pressure of the counterpressure process creates more even cell structure resulting in increased mechanical properties. Although there are numerous methods of introducing gas into the mold cavity and releasing it from the cavity—some methods more complicated than others—properly controlled, the end result is the same: smooth surfaces, uniform cell structure, and overall improved mechanical properties.

The schematic shown in Fig. 1 illustrates one way in which to perform gas counterpressure. It should be noted that the auxiliary equipment needed can be attached directly to the molding machine, or mounted on a transportable cart or table. It is important to realize that the CP process is not dependent on expensive molding equipment. Many different types of equipment have been used to produce CP parts. The molding machine itself is used only to supply signals necessary to operate the solenoid valves.

INLET SCHEMATIC

A regulator attached to the N_2 bottle allows the proper amount of gas to be delivered to the inlet solenoid. The inlet solenoid is controlled by a signal delivered when the high pressure clamp is achieved. It is then connected to the mold cavity inlets. This solenoid should remain open throughout the entire injection sequence, and should not be closed after the mold is pressurized. A check valve in proximity to the mold prevents compressed gas from backflowing in the delivery hose and returning to the source. This completes the inlet circuit. Summary: The process begins with the N_2 source, and regulator controls the N_2 from its source to an inlet solenoid though a check valve to the mold. High pressure hoses are required to connect each item.

OUTLET SCHEMATIC

The mold's outlets are connected to a solenoid valve. The outlet is different from the inlet function because the outlet line includes a pressure gauge, and/or pressure transducer, poppet valve, timer, and/or pressure switch.

THE COMPLETE NETWORK/CIRCUITRY

While the mold cavity is pressurized, the hose connecting the mold to the now closed outlet solenoid is also pressurızed. The hose, fitted with a pressure gauge, will monitor cavity

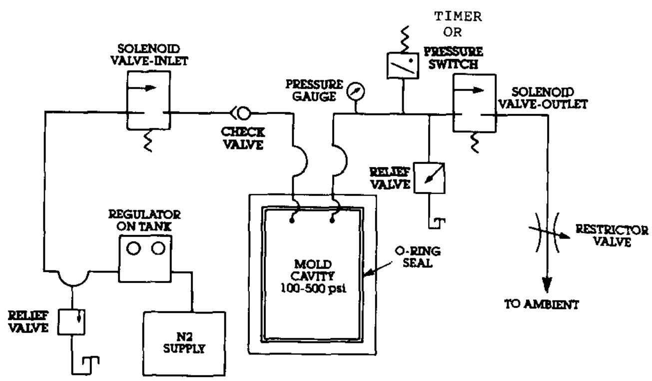


Figure 1

Presented at the Fourteenth Annual Structural Foam Conference and Parts Competition, The Society of the Plastics Industry, Inc., Aprıl 21-23, 1986, Boston, Massachusetts.

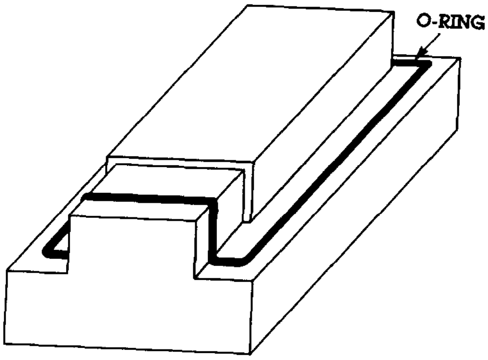


Figure 2

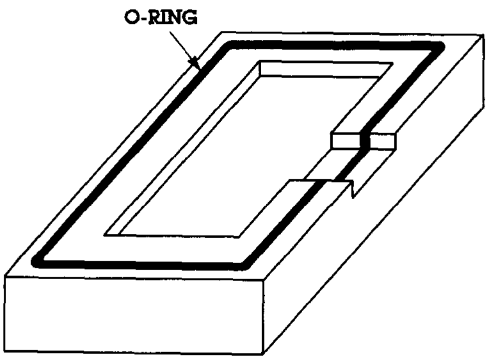


Figure 3

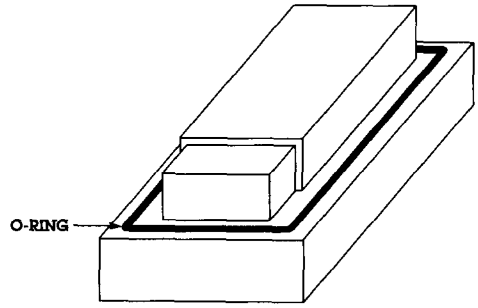


Figure 4

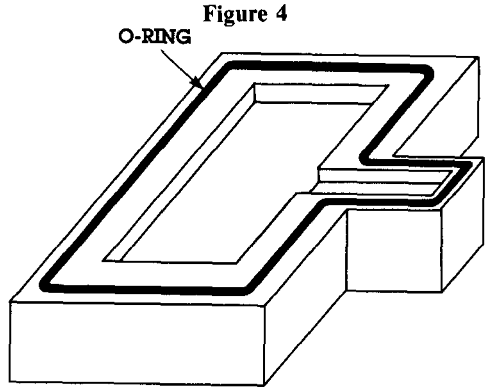


Figure 5

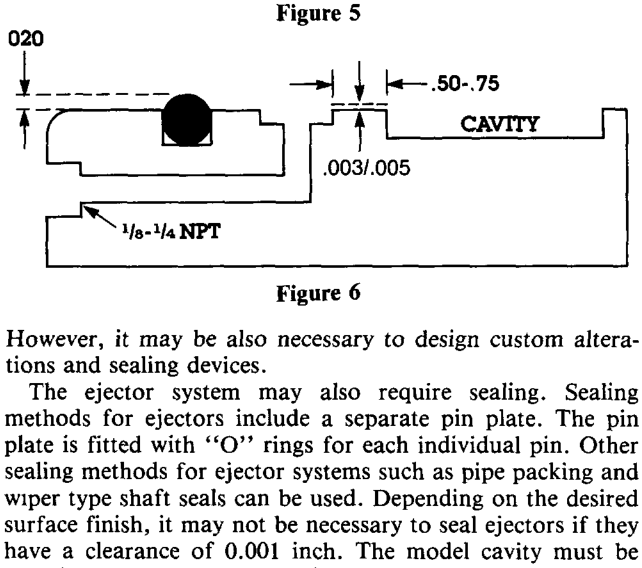


Figure 6

pressure. Pressure can also be measured with a pressure transducer connected to a chart recorder. When the line includes a poppet valve, proper pressure can be maintained in the mold. A pressure switch in the line can be used instead of a timer to signal injection.

The outlet solenoid is controlled by an adjustable limit switch on the ram. When the switch is made, the outlet valve is opened and the inlet is closed. The last step in the circuit is a restricter valve to adjust the rate of gas release.

Though it may seem complex, the opening and closing of solenoids happens within the normal molding cycle. The only addition to cycle time would be the time required to pressurize the cavity, usually one to five seconds. This schematic and sequencing will be expanded upon later in the text.

TOOLING MODIFICATIONS

To achieve a mold cavity that will maintain the desired pressure between 100 and 500 psi prior to and during injection, several sealing options are available. Tooling modifications of varying degrees will be required to obtain an adequate seal.

The first area of the mold to be addressed is the parting line. A flat parting line is recommended and is easiest to seal.

Various sizes of "O" rings, as well as numerous shapes and elastomer combinations are available and commonly used to seal the parting line. Stated in simple terms, a neoprene "O" ring of 0.210-in. diameter in a groove of 0.175-in. deep and 0.182-in. wide has proven to be a successful combination. GE Plastics' findings are based on this size, shape, and groove dimension.

In existing tools, stepped parting lines, moving cores, cams, and slides are all potential leakage areas. This is so because of difficulty experienced in sealing sharp corners or moving parts. Leakage can occur after the seal is worn or if it tears because of friction and fatigue (Figs. 2 and 3). In new tooling, leakage can be prevented by designing a flat parting line which encapsulates moving parts or stepped surfaces (Figs. 4 and 5). It is possible to adapt existing tools to achieve a proper seal. However, it may be also necessary to design custom alterations and sealing devices.

The ejector system may also require sealing. Sealing methods for ejectors include a separate pin plate. The pin plate is fitted with "O" rings for each individual pin. Other sealing methods for ejector systems such as pipe packing and wiper type shaft seals can be used. Depending on the desired surface finish, it may not be necessary to seal ejectors if they have a clearance of 0.001 inch. The model cavity must be sealed tight enough to maintain counterpressure between 100 and 500 psi prior to and during injection.

The last modifications in the mold are the gas inlet and outlet locations. These gas passage vents to and from the cavity go under the "O" ring and connect the cavity to a solenoid via high pressure hoses (Fig. 6). Inlets are manifolded on the outside of the mold and connected to a common inlet solenoid. The outlets will also be manifolded and connected to the outlet solenoid. Placement of inlets and outlets will affect the surface and proper filling of the part.

It should be understood that each CP application will require individual process development to determine proper sequence, and inlet and outlet vent locations. The following examples can be used as a guide to determine desired sequence variations and location combinations.

SEQUENCE ADJUSTMENTS

Using a pressure transducer connected to a chart recorder in the outlet side of the network, cavity pressures are monitored during the cycle. The network can also include poppet valves, a pressure switch, or a pressure gauge.

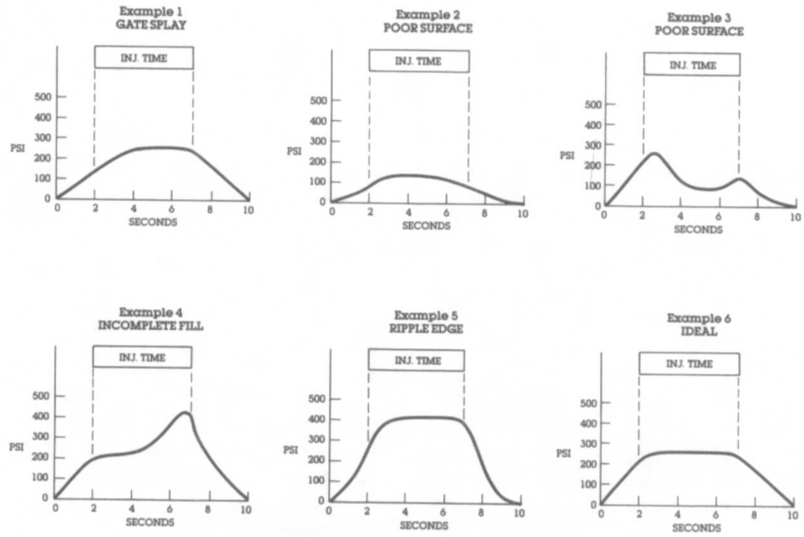


Figure 7

The cavity pressure when compared to injection time allows us to verify sequence problems that cause surface defects.

EXAMPLES OF POTENTIAL SEQUENCE PROBLEMS

1 **Not Enough Time Delay**—The example chart illustrates that when the high pressure clamp is achieved, the inlet solenoid opens. Simultaneously, N_2 is introduced into the cavity as injection begins. Initial cavity pressure at this point is not sufficient to keep the blowing agent in solution, allowing gas to break through the flow front causing surface splay. As injection continues, cavity pressure becomes high enough to contain the remaining blowing agent, causing a smooth surface in the middle and ends of flow. The result: insufficient injection delay produces gate splay.

2 **Too Low Gas Pressure/Poor Mold Seal**—Injection delay is sufficient, however, maximum cavity pressure is too low to keep the blowing agent in solution. The result: surfaces show splay throughout the part. A properly sealed model with too low gas pressure will, however, have a smooth surface at the ends of flow, because the cavity pressure is increased as the gas is compressed.

3 **Premature Inlet Solenoid Close**—Pressure is adequate before injection but is prematurely closed as injection begins. The CP process requires the inlet solenoid to remain open during injection until near completion of fill. The result: the finished part will appear smooth at the gate, but swirled in the middle and ends of flow.

4 **Counterpressure Is Not Released**—This will occur when the outlet solenoid does not open and vent in a well sealed model. Entrapped gas will result in incomplete fill, producing a partially formed part. Poorly sealed molds, those without ejector seals, sometimes act as a natural vent allowing compressed gas to escape through the ejector plate which can enable the part to fill.

5 **Too High Counterpressure**—Too high pressure causes the material to fold over itself in the mold and create shockwave type ripples when pressure is released. The result: rippled edges. This can be avoided by placing preset poppet relief values in the outlet network which will maintain maximum cavity pressure. The valves ensure that pressure never exceeds the desired amount, plus the valves give the molder more control during the process.

6 **The Ideal Sequence**—The ideal sequence allows proper injection delay to adequately pressurize the mold cavity to keep blowing agent in solution. It also provides constant pressure during injection. And it allows proper releasing of pressure to complete mold fill.

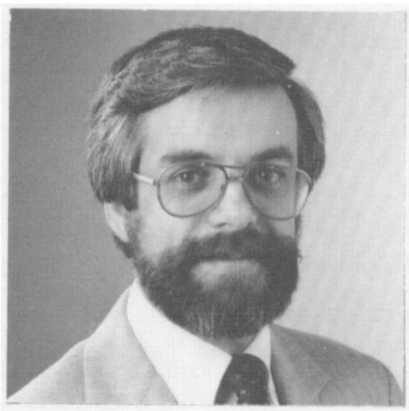
As previously mentioned, inlet and outlet locations will affect the molded part. Inlets, when placed opposite hard-to-fill areas, can sometimes help push material into that area. Outlets should be placed near knit lines and extremes of flow. The number of outlets in comparison, will usually be less than the number of vents in a traditional foam mold. It is not recommended that channels connect inlets to one another or outlets to one another. This is not recommended because it prevents total control of proper gas flow, which is necessary to achieve optimum surface finish.

SUMMARY

Once the engineering structural foam CP process network/circuitry is thoroughly understood, appropriate tooling modifications are made, and the proper sequence adjustments identified, the gas counterpressure process offers many benefits to molders and end users. These benefits include enhanced surface finish, uniform cell structure, and increased mechanical properties.

New technology advancements in the CP process continue to enable the ESF community to take advantage of these benefits while using existing equipment and by adding relatively inexpensive auxiliary equipment.

BIOGRAPHY



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