TMG News
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Getting the Most From Your Prototype Mold

Erik Foltz

The traditional design cycle of new product development has relied on the development and testing of physical prototypes. The ability to identify aesthetically pleasing designs, or validate different designs through physical testing, allows designers and engineers to collect data that may be difficult or impossible to generate through alternative virtual validation methods, such as structural analysis (FEA). When the material selected for the application is identified as plastic, it is important to consider how the production part will be manufactured to ensure the performance of the prototype part is representative of the final production part. For parts that will be manufactured using the injection-molding process that means that a prototype mold must also be constructed. With compressed design timelines and limited budgets, the details of the prototype mold and their implications on part performance, can often be overlooked. This article will highlight a few aspects of the prototype mold that needs to be considered to help ensure the measured performance of the prototype part will be representative of the final design.

Gate Type and Location

One of the first decisions with any injection-molded part is identifying where the gate will be located. The gate is the feature in which the molten plastic enters the part cavity. It is often removed after manufacturing, and therefore, considered inconsequential on the part performance. However, the gate location influences the pressure required to fill the mold, the molecular and fiber orientation in the part, the location of weld lines, and the presence of sink marks or flow lines. Therefore, the decision of gate location in a prototype mold will influence the prototype part's performance. The gate location and type can also dictate decisions regarding minimum nominal wall thickness of the part, maximum rib dimensions, and part dimensional stability.

A common use of prototype tooling, is to evaluate the feasibility of a part design that will be manufactured in a multi-cavity, hot-runner mold. Due to budget and timing constraints, the prototype mold is often "simplified" to a single-cavity that uses a cold runner, instead of a hot runner. Additionally, because the feed system design has been changed, the gate location and type will also typically change. Figure 1 shows such a part, where the production parts were to be manufactured in a multi-cavity mold, with a hot, direct gate on the top surface. However, the prototype parts were manufactured in a mold that used an edge gate at the bottom flange of the part. Changing the gate location to the bottom flange, altered how the plastic would fill in the mold, and shifted the weld line locations to different areas of the part, Figure 2. Additionally, using an edge gate changed the filling pattern in the mold (Figure 3), and influenced the dimensional stability of the part. A better option for the mold construction would have been to place the gate in the same location and use a single hot drop to fill the part. While not identical to the production tool, it would have allowed for a more representative picture of the process required to manufacture the part, and a more representative prototype part to use for validation testing.

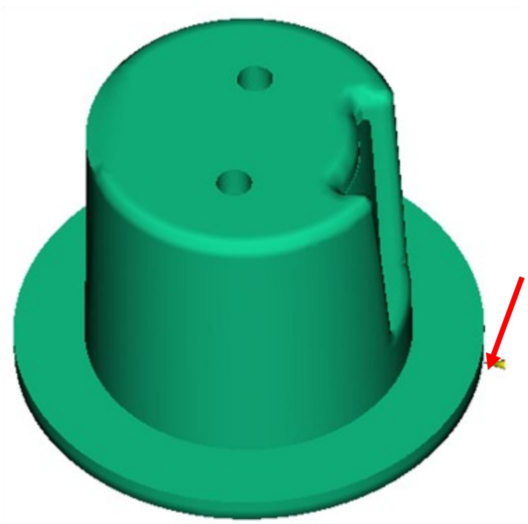
Inside This Issue:

Getting the Most From Your Prototype Mold (cont.)

Erik Foltz

Prototype Mold Gate Location (Edge Gate)

Production Mold Gate Location (Direct Gate)



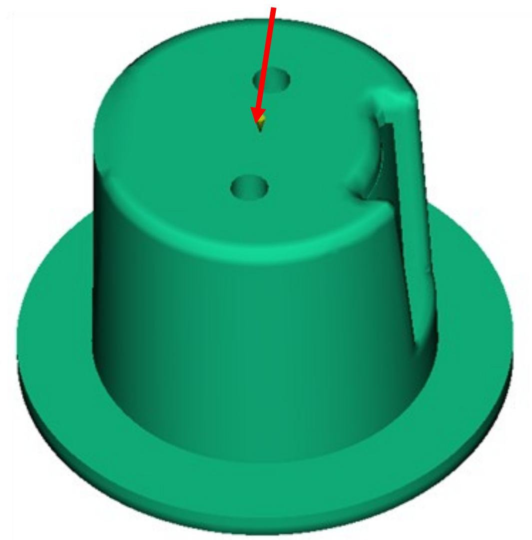
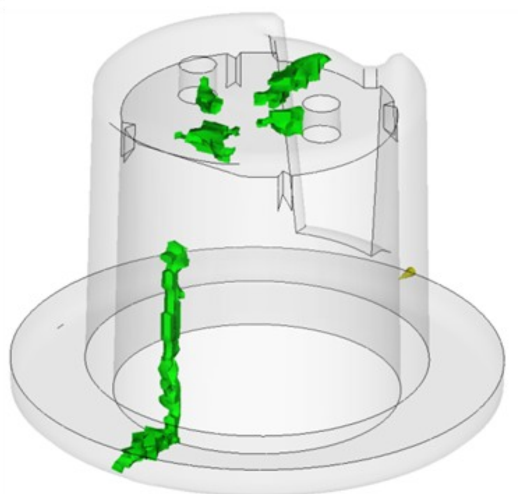


Figure 1: Images showing the different gate locations used in the prototype mold (left), and in the production mold (right).



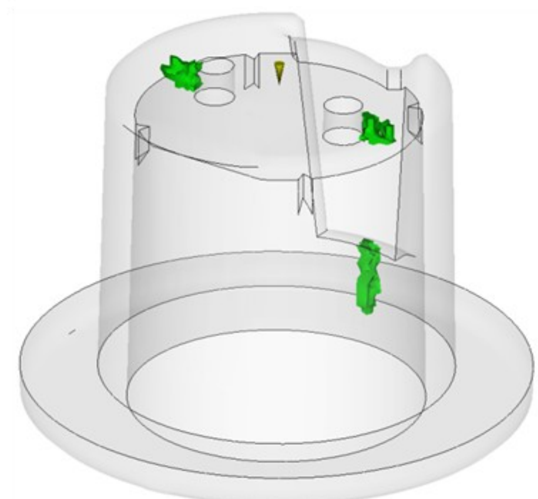
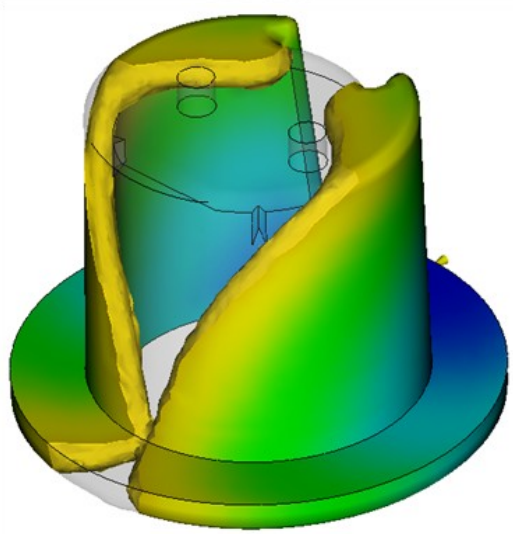


Figure 2: Images showing the change in predicted weld line locations (green lines) by modifying the gate location in the prototype mold.



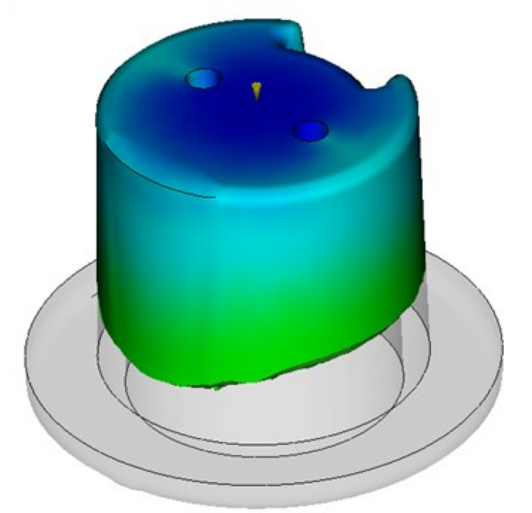


Figure 3: Images showing how modifying the gate leads to a significantly different filling pattern during injection.

Getting the Most From Your Prototype Mold (cont.) Erik Foltz

Mold Construction and Cooling Line Layout

Another aspect of prototype molds that is often overlooked is the cooling efficiency of the mold. An injection mold is essentially a heat exchanger. The cooling efficiency is dependent on the mold materials selected to manufacture the prototype mold, and the proposed cooling line layout. The combination of which mold materials to use and the cooling line placement influences not only how fast the part can be manufactured, but also influences the shrinkage rate of the material, the degree of crystallization in semi-crystalline materials, and surface appearance of the part.

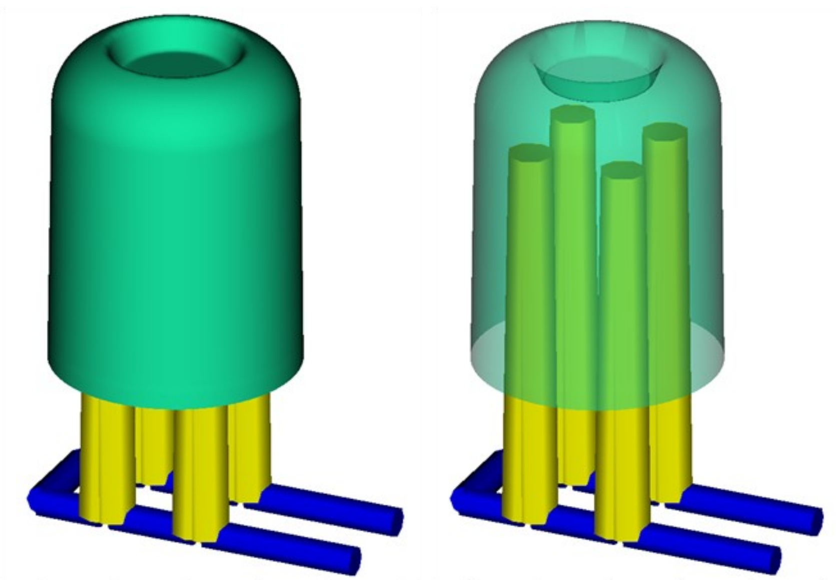
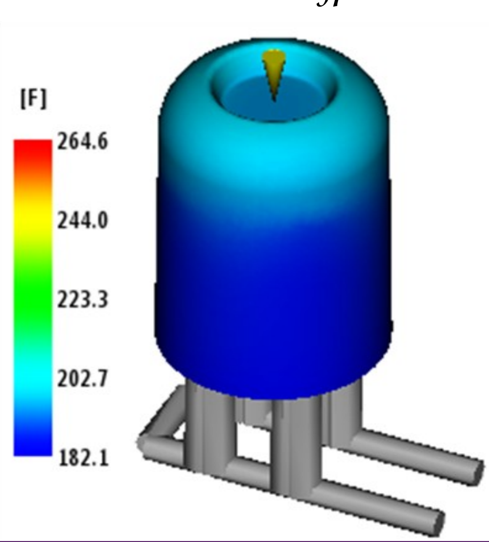


Figure 4: Images showing the cooling line layout used in a container mold.

Due to cost and lead time constraints, aluminum has been a desirable metal to select when manufacturing prototype molds. The high thermal conductivity of aluminum compared to tool steels, combined with the ability to quickly machine the cavities makes it desirable to acquire prototype parts quickly. However, using aluminum for the prototype tool, when tool steels will be used for production molds can lead to misleading results, such as the ability to maintain a uniform mold surface temperature. Since aluminum has a significantly higher thermal conductivity than traditional tool steels using the same cooling line layout in an aluminum tool, will lead to a more uniform mold surface temperature. Figure 4 shows a container mold that used that same core cooling line layout in an aluminum prototype mold, as in a tool steel production mold. The images highlight that the aluminum mold was capable of maintaining a more uniform and cooler mold surface temperature than the production tool, Figure 5. After constructing both molds, it was determined that the lower mold temperature allowed the part to be more dimensionally stable and manufactured faster than in the production mold.

Aluminum Prototype Mold



H-13 Tool Steel Production Mold

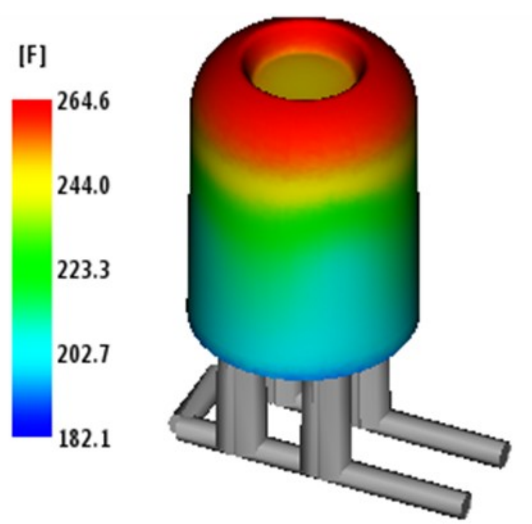


Figure 5: Images showing the predicted core mold surface temperature when the core is manufactured from aluminum (left), or from tool steel (right).

Getting the Most From Your Prototype Mold (cont.) *Erik Foltz*

The ability to manufacture and test physical prototypes of new plastic components can be an invaluable tool in collecting data during the product development process. However, a holistic approach must be taken to ensure an accurate representation of the expected part performance. Particularly, how the prototype is manufactured must be considered. Paying attention to the design and construction of the prototype tool and ensuring representative conditions are used to manufacture the prototype, will help provide engineers and designers with valuable information that will allow them to bring their product to market faster.

For more information on how to effectively prototype your plastic parts, please contact Erik Foltz at 608-231-1907, or refer to the following articles:

Gate and Runner Sizing – Why it Matters
http://madisongroup.com/publications/TMGNewsFebruary2014.pdf

Simulate Your Way to a Better Mold
http://madisongroup.com/publications/Simulate-Your-Way-To-A-Better-Mold.pdf

The Importance of Crystallinity in Plastics Performance
http://madisongroup.com/publications/TMGNewsNovember2014.pdf

Come See The Madison Group at Auto EPCON 2016 in Detroit

Erik Foltz, of The Madison Group, will be giving a presentation at this year's Auto EPCON on Tuesday, May 10, 2016. The presentation will highlight how manufacturing decisions regarding processing and material selection can influence the performance of the plastic part. The presentation will also highlight, through case studies, how these decisions can be made early on in the design stage, to avoid these potential performance issues. Those interested in learning more can contact Erik Foltz directly at erik@madisongroup.com, or register for the event here. Further details can be found below:

Title: How Processing is Affecting the Performance of Your Injection Molded Part

Presentation Time: 1:25 PM on Tuesday, May 10, 2016

Location: Detroit Marriott Troy, 200 W. Big Beaver Rd., Troy, Michigan 48084

Abstract: Optimal performance of injection-molded parts requires decisions regarding material selection, mold design, and part design to be made holistically. However, the influence of manufacturing on performance is typically limited to weld line placement. This presentation highlights how these manufacturing decisions will influence the short and long-term performance of the part.

Upcoming Educational Seminars

Joining Plastic Components – Techniques and Challenges

Importance of Mechanical Properties in Interference Assemblies
Adam Kramschuster, Ph.D. - University of Wisconsin – Stout

This presentation will focus on plastic assembly methods reliant on deformation and interference fits. For assemblies utilizing snap fits, press fits, screws, and threaded inserts, an understanding of how mechanical properties affect the integrity of the assembly will be discussed. An overview of the time and temperature dependent properties of plastics will be provided, along with how this data can be used in conjunction with material selection and assembly design to minimize failure.

Plastic Failures associated with Metal Fasteners
Jeffrey Jansen—The Madison Group

The need to secure plastic components is prevalent in the manufacture of assemblies in many industries. Joining plastic components to other plastic parts or metal parts often involves the use of mechanical fasteners, such as screws, inserts, or rivets. The joining of plastic parts is inherently more complicated than assembling two metal components because of the fundamental differences in physical properties, including strength, chemical resistance and susceptibility to creep and stress relaxation. Case Studies will be presented to illustrate failures associated with the interaction between plastic components and metal fasteners. The presented cases will illustrate how the failure analysis process was used to identify the failure mechanism as well as the primary factors responsible for the failures. The four cases depict representative failures involving varied designs and service conditions.

Joining Plastics Parts by Welding, Snap Fits and Adhesive/Solvent Bonding
Paul Gramann, Ph.D.—The Madison Group

This presentation will give an overview on joining plastic parts by welding, snap fits, and adhesives/ solvents. A review of common plastic welding methods will be given, as well as what is required for each to create a long lasting and cosmetically pleasing plastic weld. The design and functionality of commonly used snap fits, along with enhancements that increase longevity and usability, will be discussed. The presentation will review the different types of adhesives commonly used to bond plastic parts. The solvent bonding process will also be reviewed. The advantages and disadvantages of each joining method will be given so that the attendee will be more informed on what technique to employ for their application. The expected pitfalls and hurdles that commonly lead to failure will also be given. Demonstrations, examples, and case studies will be given throughout the presentation.

Attendees will come away from the presentations having a better understanding of the techniques and challenges when joining plastic components.

Educational Outreach Sponsored by:

- Society of Plastics Engineers
- UW-Stout SPE Student Chapter
- Waukesha County Technical College
- The Madison Group

The seminar is offered at two locations and is **free of charge**:

Thursday - May 5, 2016	Wednesday - June 8, 2016
University of Wisconsin – Stout Menomonie, Wisconsin 9:00-12:20: Presentation 12:30-1:30: Tour of UW-Stout Plastics Facility	**Waukesha County Technical College** Waukesha, Wisconsin 9:00-12:20: Presentation 12:30-1:30: Tour of WCTC Plastics Facility

For more information or to register, contact Jeff Jansen at jeff@madisongroup.com.

When Standard Environmental Stress Crack Resistance (ESCR) Testing Falls Short

Jake Nemec

A common chemical compatibility test for thermoplastic materials is a bent strip test where a chemical is locally applied to a specimen while under a controlled strain level, Figure 1. The strain levels selected are typically below yield, but are higher than what the part would experience in the field in order to accelerate the appearance of any adverse interactions. This test is intended to evaluate the environmental stress crack resistance (ESCR) for a plastic material. The sample is periodically inspected for cracking during the chemical exposure period, and may also be mechanically tested for property retention at the conclusion of the test. This test method is good for determining bulk chemical incompatibilities of plastic materials, and should be conducted at the onset of any new product development process where chemical exposures are known and expected.

An issue with this method is that the testing is typically performed on samples with optimal material properties, whereas failures in plastic parts often present themselves at areas of less-than-ideal material/part properties. A well-molded single end-gated tensile bar will have an optimal molecular orientation in the gage length, no significant degradation, a smooth surface, and no knit lines. Often times, the specimens may also be annealed prior to the testing to reduce molded-in stresses. This ideal material condition for the testing will almost never imitate the actual condition of a molded plastic part.

Figure 1: ESC test setups using flex and tensile bars.

A plastic part will commonly possess molded-in stress, knit lines, thickness transitions, abrupt geometric features, and varying levels of molecular weight reduction. Therefore, caution must be taken when translating chemical compatibility data generated for an ideal material specimen, to the expected performance of that material in an injection molded part.

For example, plastic materials will typically have reduced mechanical properties at a knit line. Per a knit line study conducted by BASF[1], this reduction can be as high as 20% for common unfilled materials and up to 80% or more for highly reinforced materials. The same mechanisms leading to reduced mechanical properties at the knit line will also reduce the ESC resistance of the material at the knit line. Thus, a resin that appears to be compatible with a chemical under the ideal test conditions, may suddenly start failing at the knit line after exposure to a chemical that was thought to be acceptable.

In the above scenario, a study of the chemical compatibility on a dual end-gated tensile bar with a knit line in the gage length could have revealed the incompatibility. In this situation, the typical chemical screening failed, which highlighted the need for tailoring a chemical compatibility test to the reality of the situation, not just the ideal case.

Other factors that could make normally compatible chemicals develop a heightened level of incompatibility with a molded part could be processing-induced degradation, changes in molecular weight, molded-in residual stresses, and sharp geometric features. These factors all have the effect of increasing stress levels or reducing the strength of the material, both of which will correspondingly reduce the material's resistance to potential ESC agents.

When developing a chemical compatibility test for a new product or material, take a hard look at the part design. Does it have knit lines? Does it have sharp corners? Might it have residual stress? If the answer is "yes" to any of these questions, the standard chemical compatibility test methods may not be enough.

[1] Reference: *OPTIMIZED MECHANICAL PERFORMANCE OF WELDED AND MOLDED BUTT JOINTS: PART II – WELD AND KNIT LINES INTEGRITY*. BASF Corporation. 2003. Retrieved from www.basf.com.

Upcoming Educational Webinars

Webinars provide a cost-effective way to expand your knowledge of plastics. Below is a list of the upcoming webinars presented by TMG Engineers:

Thursday, April 14, 2016—*Jeffrey A. Jansen*—Society of Plastics Engineers
Creep Failure of Plastics — 10:00 AM CST
***For more information, contact** Scott Marko at smarko@4spe.org.*

Creep is the tendency of a polymeric material to deform permanently under the influence of constant stress, as applied through tensile, compressive, shear, or flexural loading. It occurs as a function of time through extended exposure to levels of stress that are below the yield strength of the material. Given sufficient time, this can lead to creep rupture, the failure within a material as a result of continuously applied stress at a level below the tensile strength. Plastic materials are particularly prone to creep rupture through exposure to static stresses, and a recent study indicates that 22% of plastic failures are associated with creep.

The relatively high frequency of creep failure is linked to the widespread lack of awareness and understanding of the effects of time on polymeric materials, particularly at the design stage; the unique difference in time dependence between polymeric materials and metals; and the increasing use of plastic materials in diverse applications with longer time demands.

The concept of creep is extremely important to manufacturers and users of plastic components.

This webinar will cover:

- Introduction to Creep
- Plastics Failure Mechanism
- Creep Failure Mechanism
- Generalizations of Creep
- Creep Testing and Lifetime Prediction
- Creep Failure Case Studies

Thursday, May 12, 2016—*Jeffrey A. Jansen*—Society of Plastics Engineers
Basic Rubber Technology—Time 10:00 AM CST

This webinar will introduce the attendees to the basics and most important topics related to thermoset rubber compounds. About 15 billion kilograms of rubber are produced ever year. Rubber finds its way into a wide range of applications in the automotive, medical, appliance, electrical, and chemical industries. As a class of materials, rubber has many useful properties because of its unique molecular structure. These include being soft and relatively flexible, high ultimate elongation coupled with good elastic recovery, useful over a wide temperature range, and good chemical resistance.

As part of the presentation the following topics will be covered:
- Introduction to polymers – how rubber is different than plastic
- Overview of rubber properties
- How rubber compound recipes are created
- The essentials of rubber mixing and molding
- The specification of rubber compounds

***Contact** Scott Marko at smarko@4spe.org.*

Upcoming Educational Webinars (cont.)

Thursday, May 19th, 2016—*Jeffrey A. Jansen*
Failure Analysis of Plastics—Time: Noon CST
Audio Solutionz
https://www.audiosolutionz.com/chemicals/plastic-component-failure-analysis.html

Plastic components used in a variety of applications fail in the field. In many cases it is essential to ascertain the mechanism and cause of the failure. The most efficient and effective method of determining how and why the product failed, is to perform a systematic failure analysis following the scientific method. Someone once said, "if you don't know how something broke, you can't fix it", and this certainly highlights the importance of a thorough understanding of how the product failure occurs.

The webinar will introduce the attendees to the methodology needed to perform a failure analysis. Following this, the program will cover the most common tests used to identify the how and the why of plastic failure. The webinar will also cover the molecular nature of plastic failure and the four most important failure mechanisms. The webinar concludes with a number of case studies to illustrate the concepts of plastic failure analysis.

By attending this webinar, you will:

- Be familiar with the process of conducting a failure investigation
- Identify which tests can provide information pertinent to the failure
- Understand the five factors effecting plastic part performance
- Recognize the primary plastic failure mechanisms

Wednesday, August 31, 2016—*Jeffrey A. Jansen*
FTIR made Easy for Better Identification of Plastics
Special Chem

Fourier transform infrared spectroscopy (FTIR) is a fundamental analytical technique for the analysis of organic materials. It provides critical information in the evaluation of polymeric materials. The course will present a fundamental understanding of the technique including theory, applications, sample preparation, and complementary analytical methods.

Having a thorough knowledge of the subject will allow scientists and engineers using FTIR spectral data to better understand the results and apply the data to problem solving and material investigations. This includes quality control material analysis, failure analysis, and reverse engineering material characterization.

- Understand what information FTIR can provide in the analysis of polymeric materials in order to maximize polymer problem solving evaluations
- Understand what other analytical techniques provide complementary information to get the most out of polymer analysis
- Understand the challenges of sample preparation and how to overcome these obstacles to obtain optimal results
- Understand how to interpret the spectral data generated through FTIR analysis to generate the optimal results
- Understand the basic theory behind FTIR analysis so that the obtained results can be better understood

Information regarding upcoming educational opportunities can also be found at:
http://www.madisongroup.com/events.html