April 2013

The Madison Group

TMG News

This quarterly electronic plastics engineering newsletter is a service provided to clients and friends of The Madison Group. The complexity of plastics requires a continual pursuit of information in order to stay current.

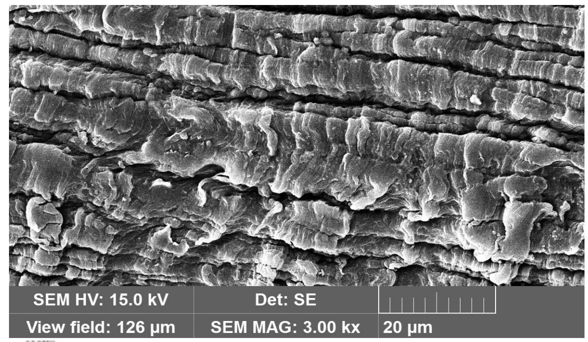
We enjoy working with our clients to help them solve their plastics problems. We also believe that it is our responsibility to help educate our clients. It is the goal of The Madison Group and this newsletter to assist in the dissemination of knowledge to plastics professionals. We appreciate your friendship and your business.

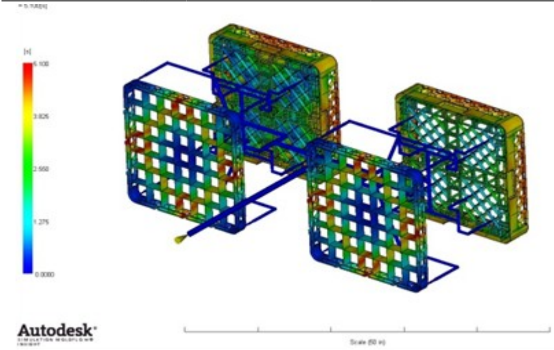
The TMG News provides plastics-related articles and information regarding educational opportunities. Working with plastic parts, whether in part design, manufacturing, material evaluation, or failure analysis, presents some unique challenges. The molecular structure and the resulting viscoelastic properties requires special knowledge.

This issue of the newsletter features an article describing the failure analysis process and its importance in root cause analysis and ultimately in problem solving. Failure analysis is an efficient and effective first step in resolving plastic part problems or nonconformance. The other article is the second of a multi-part series that addresses an in-depth treatment of poly(vinyl chloride) (PVC). PVC is an important plastic material that finds wide utility across a number of diverse applications. A case study is also included illustrating the power of simulation.

Jeff Jansen

If you do not wish to receive TMG News you can opt out by contacting me at jeff@madisongroup.com.





The Madison Group
5510 Nobel Drive Suite 215
Madison WI, 53711 USA
Ph: (608) 231-1907
email: info@madisongroup.com

Celebrating 20 Years

Inside this issue:

Failure Analysis as the First Step in Problem Solving

Jeffrey A. Jansen

When a plastic part fails there are a number of responses that can arise, as illustrated in Figure 1. At times some will deny the existence of the problem, often questioning the motives of those identifying the problem. Others decide that the problem will go away; that it is a temporary situation that warrants no further action. Experience, however, shows that plastic failures rarely resolve themselves. Such problems may subside temporarily only to resurface and often escalate. Commonly a failure prompts a team meeting in which multiple theories regarding the cause of the failure are espoused to resolve the issue. This can happen as the proposal of random opinions or as part of a Root Cause Analysis (RCA). An RCA is an organized method of problem solving that attempts to identify and correct the root causes of failure, as opposed to simply addressing their symptoms. In either case, random opinions, or RCA, the theories are commonly based upon conjecture, without scientific data. Finally, failure can be investigated using a methodology to allow science to direct the investigation. Wernher von Braun, a NASA Rocket Scientist, once said, “One test result is worth one thousand expert opinions.” Testing, whether observational, analytical, or physical, constituting a failure analysis provides the sound scientific data needed to evaluate the problem.

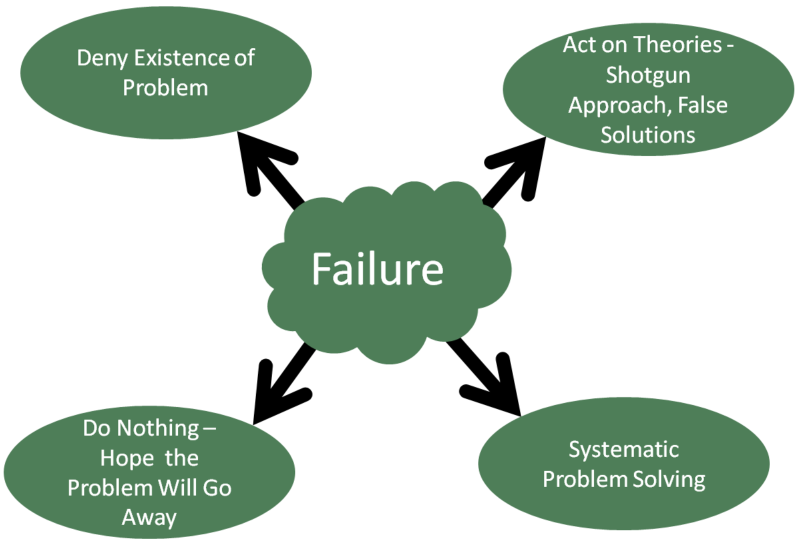


Figure 1: When a failure occurs alternative paths can be taken.

Types of Plastic Failure

- Deformation or Distortion
- Aesthetic or Cosmetic Alteration
- Degradation
- Wear
- Fracture

Figure 2: Plastic failure modes.

Failure can be broadly defined as a component or assembly that does not perform as it was intended. Using this definition, failure of plastic can occur in a number ways, not just catastrophic fracture, as listed in Figure 2. Regardless of the type of failure, a focused approach is needed to rectify the problem, and this should begin with a failure analysis. Using a failure analysis as an input for an RCA event allows the team to arrive at the true cause of the failure and implement an effective and expedient solution.

A failure analysis is a logical and systematic evaluation of a component through analytical observation and testing guided by sound engineering practices. The failure analysis process is analogous to piecing together a jigsaw puzzle. In both cases, the end result is an assemblage of many individual bits, which by themselves are often meaningless, but together create a complete picture and tell a story.

The goal of a failure analysis is to determine the mechanism and the cause of the failure, essentially how and why the product failed, in order to solve the current problem with efficient use of time and resources. Another benefit of conducting a failure analysis is that it can provide valuable information to identify ways to improve products or avoid failure in current and future parts through the identification of systemic defects or flaws in part design, the manufacturing process or installation technique. Further, the obtained data can be used to increase the knowledge related to materials, design, production methods, installation techniques, and testing methods to prevent failure.

Failures can occur throughout the product life cycle, from shortly after manufacturing the initial product launch through field failures of a mature product. Regardless, it is important that failures be addressed quickly to identify the nature of the failure and implement an expedient solution. Accordingly, a failure analysis can be performed at any point in time. Products that fail during engineering evaluations are routinely analyzed as a means to improve the component. Failures occurring while in service are commonly investigated to assess whether aspects of the product or the service environment were responsible.

The failure analyst has many tools available. Depending on the failure, the investigator may conduct the failure analysis using collected background information, macroscopic inspection, microscopic examination, compositional material testing, molecular structure assessment, and physical testing. Both non-destructive and destructive testing may be performed depending on the situation. Sometimes a concise microscopic examination of the failed product is sufficient to identify the nature of the failure without further evaluation. In other cases, a wide range of techniques and detailed analysis is required. The skill and experience of the analyst is of great importance. It is essential to have a broad understanding of the factors that influence failure and the interpretation of observational, analytical, and physical techniques.

Key Aspects of a Failure

- **Indicators - symptoms**
  What was observed that indicated a failure had occurred
- **Consequences**
  The ultimate problem to be avoided
- **Mechanism**
  How the failure occurred
- **Cause(s)**
  What was determined to be the cause(s) of the failure

Figure 3: The key aspects of a failure.

After all of the testing is completed, the failure analyst should interpret the obtained data, focusing on the essential aspects of the failure, as shown in Figure 3, particularly the failure mechanism (how the part failed) and the cause(s) (why the part failed). There are a wide variety of plastic failure mechanisms including overload, high strain rate impact, creep rupture, fatigue, environmental stress cracking, and molecular degradation. The causal factors can be associated with five parameters: material, design, processing, installation, and service conditions. With plastic component failure, it is very common to find multiple independent factors are significant in causing the failure to occur. Piecing together the mechanism and cause can be a significant challenge. After this has been completed, the information generated as part of the failure analysis makes an excellent input to RCA.

> *"If you don't know how it broke, you don't know how to fix it."*
> *Anonymous*

In spite of the obvious benefits of performing a formal failure analysis, this process is frequently overlooked in favor of pursuing pet theories. Often, this is justified based on both the cost and time required to conduct a failure analysis. A study, however, has shown that problem solving guided by material testing can save several times the actual cost of the investigation and dramatically reduce the overall time required to solve the problem[1]. The primary risk in acting without the guidance that is provided by the test results is addressing the wrong issue when attempting to solve the problem. Pursuing false solutions consumes significant resources and wastes valuable time, while not contributing to a solution to the true problem.

The outcome of the failure analysis identifies the mechanism of the failure and the causal factors. After completing the failure analysis, most of the puzzle pieces are in place. However the root cause of the failure may not be clearly evident. The information obtained through the failure analysis can be used as the basis for further root cause identification so that the problem can be rectified. A useful methodology is to use the causes identified during the failure analysis as the input for an RCA technique known as Event and Causal Factor Charting. This charting is a flexible tool for analyzing the chronological events and causal factors of a failure. A timeline, including related conditions, secondary events, and presumptions, is created. The goal is to identify the key equipment failures, process failures, environmental factors, or human errors that led to failure, particularly recognizing those key factors, that if eliminated, would prevent failure. This process can be continued by using another RCA method, the Five Whys technique. Five Whys is a simple technique to lead the user to deeper levels of causal understanding. The idea is to ask why repeatedly after identifying the cause(s), ultimately leading to the root cause. By combining these three separate techniques - Failure Analysis, Event and Causal Factor Charting, and Five Whys - the root cause of the failure can likely be identified. An example of the systematic approach is illustrated by the failure of a relatively high number of personal medical monitors in service. Through failure analysis, the following aspects were determined:

[1] Michael Sepe, "The Price of Testing and Not Testing", Injection Molding Magazine, November, 2001

Key Aspects of Medical Monitor Failure

Indicators – symptoms: Battery covers fell off of mobile medical monitors
Consequences: Potential for loss of patient monitoring
Mechanism: Low cycle fatigue
Causes: Massive molecular degradation from processing
Design with sharp corner – stress concentrator
Under-crystallized during molding
Improper pigment system in resin

Putting all of the information together, the timeline including the failure analysis inputs leading to the conditions and the associated secondary events, and the root causes is shown for the personal medical monitor failures, in Figure 4. Through this process, the root causes were determined to be the unfamiliarity of the unique design requirements of plastics to the design engineers; the lack of knowledge regarding the incompatibility of the plastic used in the application with certain pigment systems; improper maintenance of the equipment used to dry the resin prior to molding; and the focus of the molder on producing a high number of parts per hour rather than producing high integrity parts.

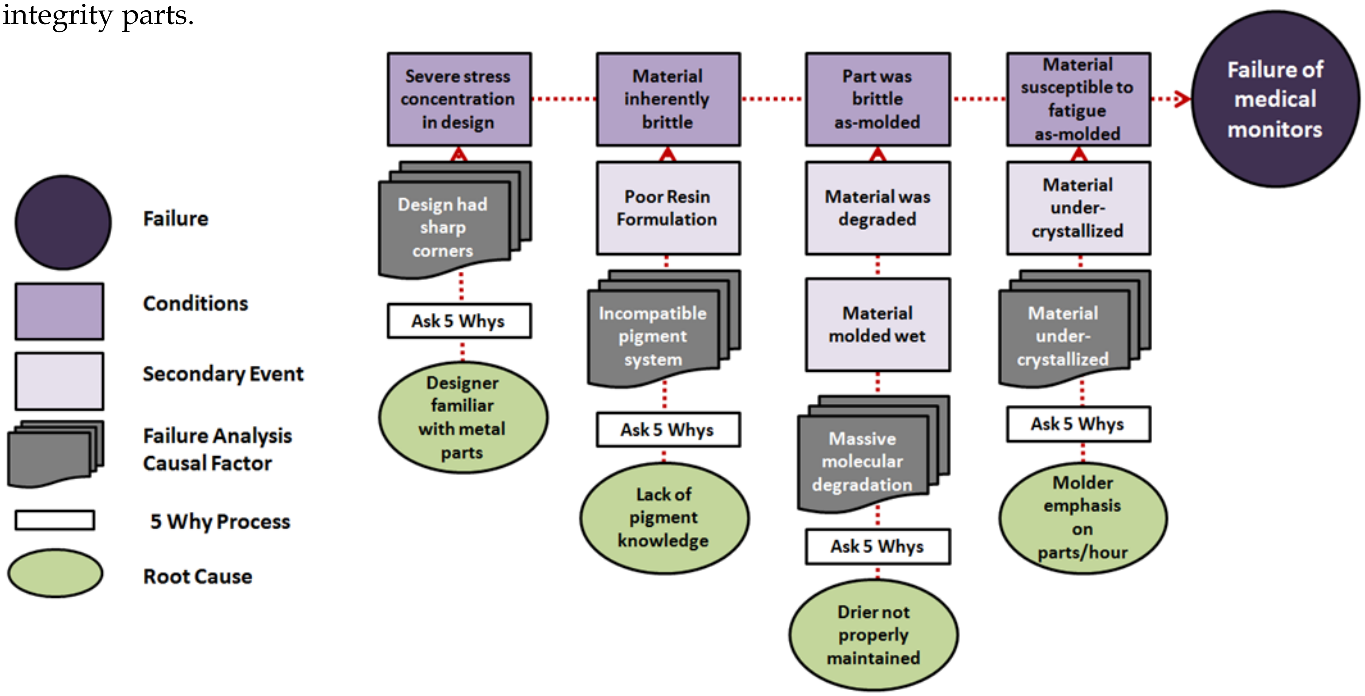


Figure 4: Example showing the root cause evaluation of failures of personal medical monitors.

By using a systematic approach and conducting a thorough failure analysis followed by root cause analysis, the underlying causes of plastic component failure can be identified. This is well illustrated by the personal medical monitor example. It is unlikely that one, let alone all four, of the underlying causal factors would have been identified during a Root Cause Analysis (RCA). without the input from the failure analysis. Root Cause Analysis can be a powerful technique. However, without the benefit of the scientific data from a failure analysis the results on the RCA are laden with speculation. The combination of the failure analysis and RCA methodology provides a timely, cost-effective way to solve plastic component failure.

If you would like more information regarding a failure analysis, or other plastics issues, please contact The Madison Group at 608-231-1907, or email at jeff@madisongroup.com.

For further information regarding plastic part failure read the following papers authored by the staff at The Madison Group (click on the link to access the paper).

Finding Fault: A Partial Failure Analysis Needed to Part Problems

Failure Analysis of a Polysulfone Flow Sensor Body — A Case Study

The Evaluation of Appliance Hose and Tubing Failures

Educational Seminars

The Madison Group together with the University of Wisconsin - Stout and sponsored through the Society of Plastics Engineers will be offering a free half-day seminar. The seminar, entitled **"Understanding Time and Temperature Effects in Plastic Part Design, Processing, and Performance – What You Really Need to Know"**, will use case studies and practical examples to help plastics professionals understand the effects of viscoelasticity during design, material selection, manufacturing, and service. Accounting for the time- and temperature-dependent material properties of plastics will help to ensure product success.

However, the data given on material datasheets are limited to a narrow window of conditions that do not adequately describe how the molded resin will behave in service. Relying on the datasheet may not provide a good indication of the suitability of the resin to endure the demanding and specific performance requirements that the engineer and designer anticipated. Failure to consider this behavior can lead to greater expenses associated with material waste from over-designed parts or increased warranty rates from premature failures. Three separate presentations will focus on the practical aspects of viscoelasticity and how simulation and material testing can be used to address these design and performance issues.

*The attendees will come away from the presentation having a better understanding of **creep**, **stress relaxation**, and **lifetime prediction,** and why they are important in designing, manufacturing, and using plastic components.*

Presenters:
Dr. Adam Kramschuster of University of Wisconsin – Stout
Jeffrey A. Jansen of The Madison Group
Erik Foltz of The Madison Group

The same seminar will be conducted at two separate locations:

Location 1
University of Wisconsin Stout; Menomonie, Wisconsin
Tuesday, May 14, 2013
9:00 to 12:20 Presentation
12:30 to 1:30 Tour of UW-Stout Plastics Facilities

STOUT
UNIVERSITY OF WISCONSIN

Location 2
Waukesha County Technical College; Waukesha, Wisconsin
Monday, June 10, 2013
9:00 to 12:20 Presentation
12:30 to 1:30 Tour of WCTC Plastics Facilities

WCTC
waukesha county technical college

Cost: **Free of Charge**

The seminars are being presented as an educational outreach between The Madison Group, the UW-Stout SPE Student Chapter, and Waukesha County Technical College Industrial Division. To register or obtain more information, contact Jeff Jansen of The Madison Group at 608-231-1907 or jeff@madisongroup.com.

Society of Plastics Engineers

PVC Part 2: Processing

Javier Cruz, Ph.D.

As previously discussed in Part 1, the mechanical performance of PVC is primarily controlled by the use of numerous additives. The same is true for optimizing the processing characteristics. Additionally, many additives perform more than one function. For example, plasticizers will increase flexibility of the material for a given application, but they will also reduce the viscosity and lower the glass transition temperature (Tg) creating a softer polymer easier to process. Plasticizers aid in processing by acting as extenders and lubricants improving the material flow behavior. For this reason, it is more difficult to process unplasticized PVC (PVC-U) which will be our topic of interest.

In order to properly process PVC-U, processing aids are an absolute necessity. Processing without critical additives such as heat stabilizers and lubricants would likely result in degraded polymer for every single part since it would degrade at nearly the same temperature needed to process the material. Processing aids are also necessary to increase elasticity and the ability of the melt to stretch. This is critical because it will control the ability of the material to properly shear and break down the PVC particles to increase the degree of fusion.

Degree of fusion is not a common term for many plastics and the reason is that PVC synthesis is unique when compared to most other polymers. PVC is insoluble in vinyl chloride − the monomer used to synthesize it. Therefore, as PVC is synthesized, it bundles in particulates that separate from the monomer solution resulting in a powdery end polymerization product, Figure 1. There are benefits to this unique reaction, as well as disadvantages. One benefit is that monomer removal during polymerization happens naturally resulting in very low monomer content products that are ideal for food and medical applications. Unfortunately, this powdery material can be very difficult to process which explains the need for processing aids. However, if the processing conditions are not optimal, PVC particulates can easily bundle and cause poor material fusion, even with adequate processing aids.

Figure 1: PVC powder.

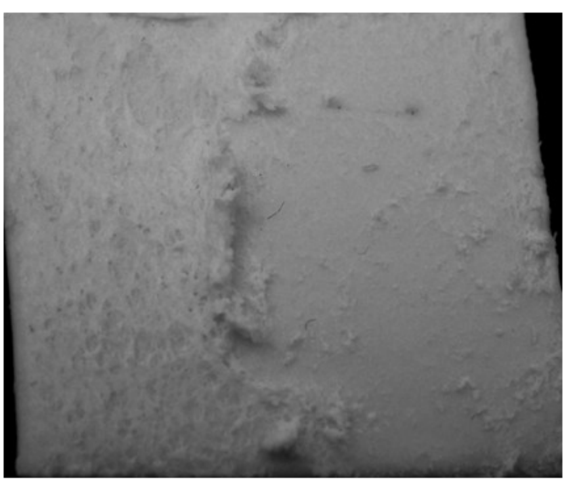


Figure 2: Material lifting due to poor fusion.

Degree of fusion can therefore be described as the ability of these particulates to break down and rejoin as a solid structure. Since PVC is a polymer, rejoining of these particulates needs to happen at the molecular level from proper molecular entanglement. As with other polymers, temperature and shear are the critical variables necessary for the polymeric molecules to properly interact and entangle. Poor fusion in PVC will result in brittle characteristics and low end-performance.

There is a variety of methods for evaluating degree of fusion from processed PVC parts. Two qualitative techniques are the acetone immersion test (AT) and the dichloromethane test (DCMT). The first follows ASTM D2152 while the second follows ISO 9852 standard. These tests focus on looking at the surface of the material when exposed to the respective chemicals and only provide a qualitative evaluation of the material's degree of fusion based on visual signs of material lifting or removal, Figure 2. A more quantitative technique is DSC-fusion testing which follows ISO 18373-2. This technique provides the benefit of quantifying the degree of fusion and has shown to be extremely valuable for many failure analysis investigations. The DSC analysis not only provides information on the degree of fusion, but can also provide a reference of melt temperature value attained during processing. Figure 3 shows a pipe with a low degree of fusion due to poor processing that severely cracked during normal use.

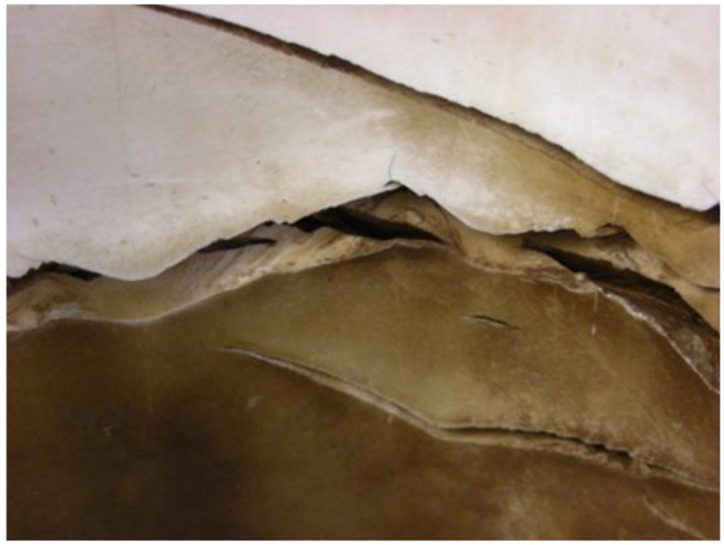


Figure 3: Pipe that failed during use due to poor fusion.

When considering fusion, it makes sense that a higher temperature and shear experienced by the material should result in better properties due to a more complete fusion. On the other hand, scholars have presented data suggesting that certain properties such as impact strength show a maxima at a specific degree of fusion that can be below the highest achievable fusion. However, with PVC's narrow processing window, more data is needed to properly account for the relationship between degree of fusion and degradation effects during processing.

PVC resin will easily degrade at processing temperatures. This makes processing of PVC a difficult task. Typical melt temperature ranges for injection molding grade PVC resins are 160-220°C. In general, injection and extrusion processes try to maintain the melt temperature below 200°C to prevent excessive degradation. PVC can even begin to degrade below 160°C. Therefore, at processing temperatures, the only thing preventing PVC from rapidly degrading are the heat stabilizers and additives that are partially being consumed.

Figure 4: PVC Pellets.

Today, PVC material can be effectively processed through advancements in equipment design and resin formulation. For example, optimal injection molding of PVC has only been achieved after improvements in thermal stability and processability of the melt by use of additives. Furthermore, a prior compounding-pelletizing process is necessary to form the powdery PVC resin into injection moldable pellets, Figure 4. During the compounding and pelletizing process, it is critical that the material forms into pellets while preventing a high degree of fusion. This will guarantee that the compounding process will not interfere with the ability of the pellets to melt and flow when injection molded.

Even with the current advancements in formulation, processing equipment designers need to consider the poor temperature resistance of the material. Critical variables taken into account are temperature, residence time, and flow restrictions that can increase shear and create stagnation areas. For example, injection molding runner systems and gates should be approximately 20-40% larger in cross-sectional area than the conventional design used for other rigid amorphous polymers like polystyrene to minimize shear heating. Additionally, sharp corners should be avoided. Comparable to injection molding, similar conditions are desired in extrusion processes. The counter-rotating twin screw extruder is the equipment of choice for extruding rigid PVC pipes. This type of extruder is currently one of the best for plasticizing powdered raw materials. When compared to a single screw extruder, the twin screw provides unique benefits for such a heat-sensitive material. These extruders provide a high throughput with lower screw speeds while still achieving good heating, mixing performance, and reduced degradation. Dies used for PVC pipe are also uniquely designed with specific spider mandrels with flow channels that allow proper melt separation and rejoin, while avoiding melt stagnation and thermal and mechanical inconsistencies.

Parts with thin geometries can lead to high shear and degradation making them difficult to manufacture. However, thick PVC parts such as large extruded pipes can also be extremely difficult to optimally process. Most PVC fusion problems we observe are generally related to parts with thick cross-sections where there can be broad temperature differentials and lower shear in the material during processing. Whichever the process method, the low processing window of PVC resin can make optimal manufacturing a difficult task. Therefore, it is very important to consider and evaluate the true melt temperature and shear conditions that the PVC material might experience during processing. This will not only prevent fusion issues, but can also avoid failures at material rejoin areas such as meld and weld lines. Additionally, being able to characterize the final properties of the material, any degradation effects, and the degree of fusion can provide better insight of the long-term performance of the product.

Look for the final installment PVC: Part 3 in the next TMG News.

If you would like more information regarding materials engineering, or other plastics issues, please contact The Madison Group at 608-231-1907, or email at javier@madisongroup.com.

For further information regarding PVC read the following papers authored by the staff at The Madison Group (click on the link to access the document).

PVC Part 1: It's All About Composition

Using DSC to Determine the Quality of PVC

Study of the Freezing Phenomenon on PVC and CPVC Pipe Systems

Fractographic Characterization of Pipe and Tubing Failures

Upcoming Society of Plastics Engineers Webinars

Educational Opportunities - SPE Webinars

Webinars provide a cost effective way to expand knowledge of plastics. The Society of Plastics Engineers (SPE) offers a wide selection of high quality webinars, many of which are taught by experts within The Madison Group. Below is a list of the upcoming webinars:

The Effects of Impact and Other Rapid Loading Mechanisms on Plastics Jeffrey A. Jansen
Wednesday, May 1, 2013 10:00 a.m. Central Time

Weldlines: the Good, the Bad and the Ugly Erik Foltz
Wednesday, May 8, 2013 10:00 a.m. Central Time

Basic Rubber Technology Jeffrey A. Jansen
Tuesday, July 16, 2013 10:00 a.m. Central Time

Thermal Analysis in Failure and Compositional Analysis Jeffrey A. Jansen
Thursday, September 12, 2013 10:00 a.m. Central Time

Multi-factor Failure of Plastics Jeffrey A. Jansen
Wednesday, November 6, 2013 10:00 a.m. Central Time

For more information on the courses or to register, contact SPE's Barbara Spain at 203-740-5418 or bspain@4SPE.ORG.

TMG Engineers at ANTEC

The Annual Technical Conference of the Society of Plastics Engineers (ANTEC) is being held in Cincinnati, Ohio starting Monday, April 22 and concluding Wednesday, April 24. Engineers from The Madison Group will be attending ANTEC. However, more than just attending TMG engineers will be actively participating. Engineers from The Madison Group have authored three papers this year and will be presenting their work as part of the technical program. See the abstracts and presentation details on the next page.

Additionally, engineers from The Madison Group had been asked to participate in other ways.

Paul Gramann	**Introduction to Plastic Failure Analysis and Prevention**	**Tuesday April 23 4:00 to 5:00 p.m.** **Check the final program for location**
Jeffrey Jansen	**What Went Wrong–Polymer Failure Analysis using FT-IR and other techniques.**	**Tuesday, April 23 2:30 to 3:00 p.m.** **Wednesday, April 24 12:00 to 12:30 p.m.** **Thermo Fisher Booth 523**
Jeffrey Jansen	**Meet the Expert—Open Discussions**	**Tuesday, April 23 10:00 a.m. to 12:00** **SPE Booth 111**

Dr. Paul Gramann has been invited by SPE's Injection Molding Division to present a tutorial on failure analysis entitled, *"Introduction to Plastic Failure Analysis and Prevention"*.
Tuesday April 23 from 4:00 to 5:00 p.m.
Plastic failures are very common in industrial, household and commercial settings that can lead to large losses. These failures can be caused by improper material specification, bad design, improper installation, over loading and/or incorrect molding conditions. Issues such as chemical resistance, environmental deterioration, geometric sensitivity, temperature dependence and aging are at times overlooked. Various forensic techniques exist to help identify why a plastic part has failed. This knowledge will assist in allocating responsibility for its failure. The presentation will give an intriguing look at plastic failures and how one disseminates why the failure occurred. This will be done in part with some demonstrations. This seminar will cover why some plastic parts are prone to failure and discuss forensic methods to uncover the root cause. Several demonstrations will be given on how and why plastics fail.

Jeff Jansen has been asked by Thermo Fisher Scientific to give a presentation within their booth in the exhibit hall. The presentation will focus on the application of Fourier transform infrared spectroscopy (FTIR) in determining the root cause of plastic failure. The presentation will be given twice.
What Went Wrong – Polymer Failure Analysis: Root cause analysis of failed plastic parts using FT-IR and other techniques.
Thermo Fisher Booth: 523
Tuesday, April 23 2:30 to 3:00 p.m.
Wednesday, April 24 12:00 to 12:30 p.m.

Jeff Jansen will also be appearing in the Society of Plastics Engineers (SPE) booth as part of a program entitled "Meet the Experts".
Meet the Experts is a program that allows access to plastics experts for individualized open discussion. Jeff will address questions on failure analysis, plastic performance, material selection, and other related topics.
SPE Booth: 111
Tuesday, April 23 10:00 a.m. to 12:00 p.m.

For more information on attending ANTEC visit the SPE website at www.4SPE.org.

The Madison Group ANTEC Papers April 22 and 23, 2013

Engineers from The Madison Group will present three papers at this upcoming ANTEC, the Annual Technical Conference of the Society of Plastics Engineers to be held in Cincinnati Ohio.

The Role of Multiple Factor Concurrency and Statistical Distribution in Plastic Part Failure

Jeffrey A. Jansen and Antoine Rios, Ph.D., The Madison Group
Monday April 22, 10:00 a.m., Session M9

When a plastic part fails, a tough question is often asked, "Why are a limited number of parts failing?". This is particularly true with seemingly random failures at significant, but low, failure rates. Two aspects are generally linked to such low failure rates, multiple factor concurrency and the statistical nature of plastic failures. Failure often only takes place when two or more factors take effect concurrently. Absent one of these factors, failure will not occur. Plastic resins and the associated forming processes produce parts with a statistical distribution of performance properties, such as strength and ductility. Likewise, environmental conditions, including stress and temperature, to which the resin is exposed through its life cycle is also a statistical distribution. Failure occurs when a portion of the distribution of stress on the parts exceeds a portion of the distribution of strength of the parts. This paper will review how the combination of multiple factor concurrency and the inherent statistical nature of plastic materials can result in seemingly random failures.

Effects of Biodiesel on Plastics

David Grewell, Tong Wang, Melissa Montalbo-Lomboy, Linxing Yao, Iowa State University,
Paul Gramann, Ph.D and Javier Cruz, Ph.D., The Madison Group
Monday April 22, 1:30 p.m., Session M29

Many chemicals have the ability to attack plastics leading to failure. In some cases, the source of the chemical is not well defined. In this study, the effect of biodiesel, a fatty acid methyl ester, on various plastics, namely polyamide 6 (PA 6), polycarbonate (PC), acrylonitrile-butadiene-styrene (ABS) and ABS/PC plastic blends was studied. Various feedstocks of biodiesel were also studied, including, soy bean oil (new and used), animal fat (tallow), corn oil as well as choice white grease. The plastics samples were tested following an ASTM standard where a predefined strain is applied to the samples prior to exposure to the solvent (biodiesel). This study has shown that biodiesel can be incompatible with engineering plastics, such as PC, ABS and ABS/PC blends.

Effects of Glycerin Antifreeze on CPVC

Paul J. Gramann, Ph.D., and Javier C. Cruz, Ph.D., The Madison Group
David Grewell, Ph.D, Melissa Montablo-Lomboy,Ph.D, and Tong Wang, Ph.D., Iowa State University
Monday April 22, 2:00 p.m., Session M29

There are multiple applications where chlorinated poly(vinyl chloride) (CPVC) may come in contact with glycerin. One common application is in fire suppression systems that could be subjected to subfreezing temperatures. Chlorinated poly(vinyl chloride) is increasingly being used for these systems in place of metal because of its many advantages, including the ease of installation, weight reduction, cost benefits and chemical resistance. When CPVC piping is used in an area that has the potential to freeze, an antifreeze solution must be used in the fire suppression systems to suppress the freezing temperature of the water and reduce possibility of failure of the piping system. Glycerin is a commonly used antifreeze for this application. The following article discusses the effects of using glycerin with CPVC piping and presents a case study of the use of bio-derived glycerin as an antifreeze agent. In general, it was found that glycerin from the bio-diesel industry had adverse effects on the CPVC.

From the TMG Solutions Archives:

Rain Barrel Analysis

Keywords - Failure, Creep, FEA, Design Evaluation

What Went Wrong?

A plastic rain barrel was cracking at the bottom of a stiffening rib after approximately two weeks in service, which resulted in leakage of water. The rain barrel was injection molded from a high-density polyethylene material.

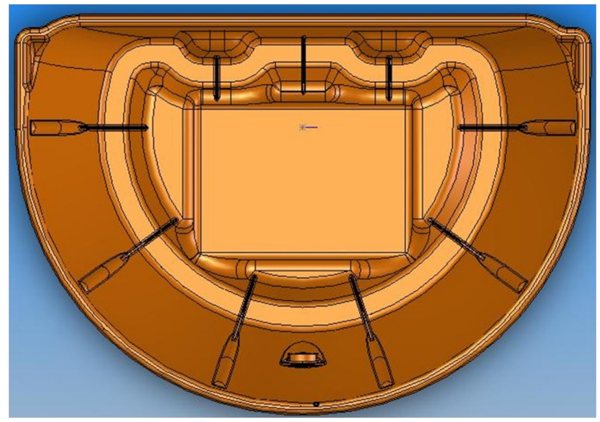
Evaluation

A visual examination of the failure revealed a smooth fracture surface that initiated at the base of the rib. The fracture surface was characteristic of a brittle fracture mechanism known as creep. Creep is a material response mechanism, commonly experienced by plastics and composites, in which the molecules of the plastic separate under the influence of a constant stress that is below the yield stress of the material.

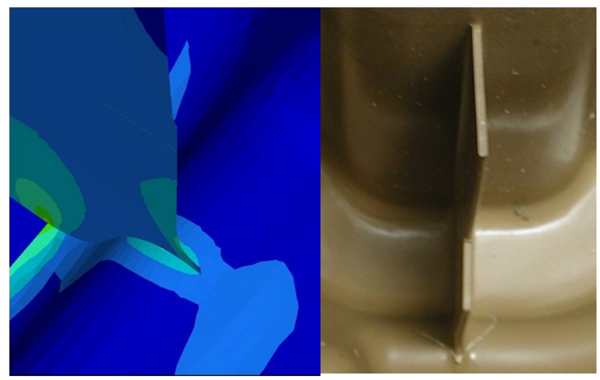
The design integrity of the rain barrel was evaluated by performing a series of material tests and structural finite element analysis (FEA). The material testing used dynamic mechanical analysis (DMA) to characterize the long-term mechanical properties of the resin while under load. The FEA was used to determine the stress distribution in the rain barrel when the barrel was filled with water. The FEA confirmed the area of high stress coincided with the failure location, and the stress remained below the yield point of the plastic material. Combining the results of the material testing and the FEA allowed for a prediction to be made regarding the amount of time until the rain barrel would fail. With the stress levels predicted in the FEA, the rain barrel was predicted to fail after approximately two weeks of service.

Conclusion

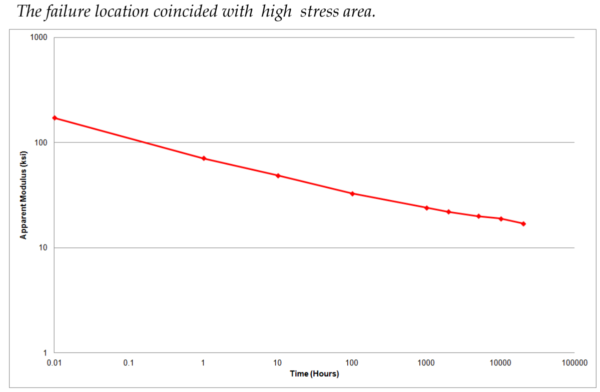
It was the conclusion of the evaluation that the rain barrel failed through a brittle fracture mechanism known as creep. The combination of the rain barrel design and material selected resulted in a stress level that left the rain barrel susceptible to premature failure when filled with water. It was recommended that a either the design of the rain barrel be modified or the plastic should be changed to a more creep resistant material.



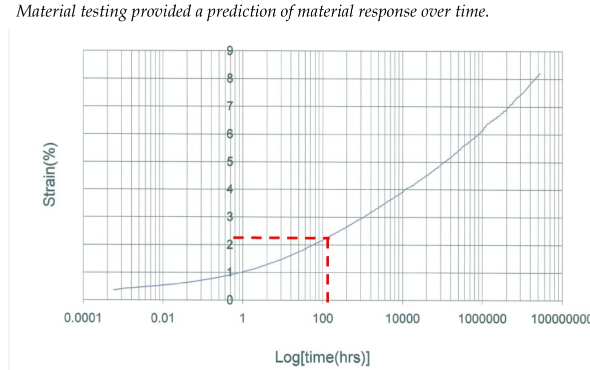
Top view of rain barrel design.



The failure location coincided with high stress area.



Material testing provided a prediction of material response over time.



Failure was predicted to occur after two weeks of service.

The Madison Group
5510 Nobel Drive Suite 215
Madison WI, 53711 USA
Ph: (608) 231-1907
madisongroup.com