TMG News

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Importance of Drying

Erik Foltz

Pay Attention to Drying to Help Ensure Your Part Performance

Engineers and designers spend a significant amount of time and energy selecting the proper plastic material to ensure their part will perform optimally. Integration of tools, such as structural finite element analysis (FEA) and injection molding simulation, into the design cycle can help designers optimize their mold design and process to maintain the natural attributes of the polymer selected. However, these tools are primarily used to identify potential issues that could occur once the material is injected into the mold. They do not provide any information about what happened to the material prior to being injected. While issues during inspection are still important to address to help minimize any potential material degradation during molding, they are not the only sources of degradation that can be occurring during processing. Proper handling of the plastic resin, and specifically, proper drying of the resin, is also critical to ensure proper part performance.

Hygroscopic vs. Non-Hygroscopic Materials

Most are familiar with the differentiation of amorphous and semi-crystalline polymers. However, polymers can also be classified as being hygroscopic or non-hygroscopic. Many polymers, like nylon, polycarbonate and polyurethane attract moisture from the surrounding air, and are classified as hygroscopic. Non-hygroscopic resins, such as polyethylene or polypropylene, do not absorb any moisture.

The ability of hygroscopic resins to pull moisture from the surrounding air is a consequence of the chemical make-up of the polymer chains. These chains contain polar functional groups that attract the water molecules present in the air, and attach it to the polymer backbone. As Figure 1 shows, hygroscopic polymers start to attract moisture as soon as the material is exposed to air. The amount of moisture the resin will absorb is a function of the polymer, atmospheric conditions, and exposure time. Table 1 (*see Page 2*) provides a brief list of polymers that require drying prior to processing.

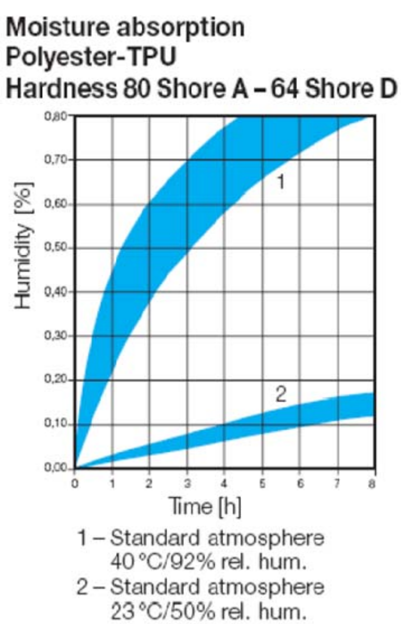

Figure 1- Graph produced by BASF highlighting the rate at which a TPU resin will absorb moisture from the surrounding atmosphere.

The Reason for Drying

If the moisture that these hygroscopic resins absorb is not removed prior to processing, the quality of the molded product could be diminished. In some cases, the consequence of improper drying is only a cosmetic concern. The appearance of splay, or irregular flow patterns in the molded part are symptomatic of improper drying. However, in other cases the presence of moisture can actually trigger a chemical reaction called hydrolysis.

During hydrolysis, the water molecules shorten the long polymer chains, and reduce

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the molecular weight of the polymer. This reaction results in the possibility of reduced mechanical properties in the final molded parts.

Hygroscopic: Cosmetic Concerns	Hygroscopic: Performance Concerns
ABS	PET
SAN	PBT
PMMA	PC
PPE/HIPS	PA (Nylon)
PPS	PU
POM	PLA

Table 1: Table highlighting some common polymer families that the need for drying them prior to processing.

To avoid these cosmetic and performance issues, the plastic pellets are put into a dryer prior to molding. The dryer is a separate piece of equipment from the molding machine, in which hot dry air flows over the plastic pellets to pull the water away from the polymer backbone. Hygroscopic resins that are dried for cosmetic reasons typically can be processed with moisture levels as high as 0.05% to 0.10%.[1] However, resins that are dried to avoid hydrolysis typically require moisture contents of less than 0.02%. To reliably and consistently achieve this low of a moisture content, these resins will need to be dried in a desiccant dryer where the air is conditioned to achieve a dew point of -40 °F. The length of time to dry the material varies based on material and the type of dryer used. Most resin manufacturers provide guidelines on the amount of time and temperature the resin should remain in the dryer.

What to do After Drying the Resin

While the resin suppliers do provide guidelines on what the air temperature should be in the dryer, and the amount of time it should take the resin to achieve the desired moisture content, it should not be used as the only criteria for identifying proper drying. The effectiveness of the dryer is dependent on many parameters including, air flow, air temperature, and dew point. Therefore, to ensure the dryer is operating properly, the dried resin should be tested for moisture content prior to molding using a moisture analysis technique. The moisture of the dried resin typically cannot be measured real time in the dryer, but rather, must be removed and tested with a moisture analyzer. The use of the moisture analyzer helps to confirm that the material has reached the desired moisture level, and can be used to help identify potential maintenance issues with the dryer.

Once the material has been properly dried, it can now be processed and introduced to the hopper. Depending on the equipment of the molder, the resin may be conveyed to the molding machine in a closed tube system, or manually removed from the dryer to the hopper. Either way, once the dried resin leaves the dryer and comes into contact with the atmospheric air, it will start to re-absorb moisture. Therefore, the resin should be processed as soon as possible after being removed from the dryer. If the material spends a significant amount of time in the hopper the effort of drying the resin may be lost.

Proper drying of plastics prior to molding is a critical step in the successful manufacture of plastic products. While some molders may see it as an inconvenient step required to process the material, the elimination of it will surely lead to issues later on in the supply chain. Additionally, paying attention to the proper drying conditions and ensuring the material is at the correct moisture content, will help maintain the natural attributes of the material selected for the application.

If you would like more information regarding plastic failure, or other processing issues, please contact The Madison Group at 608-231-1907, or email at erik@madisongroup.com.

[1] "Drying Technology Drying Done Right, Plastics Technology February 2015."

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, February 11, 2016—*Jeffrey A. Jansen* – Society of Plastics Engineers
Environmental Stress Cracking—11:00 am EST
"Environmental Stress Cracking" will provide you with information that will enhance your understanding of the interaction between chemicals and plastic resins, and help prevent premature failure. Environmental stress cracking (ESC) is a phenomenon in which a plastic resin is degraded by a chemical agent while under stress, and it is a leading cause of plastic component failure. It is a solvent-induced failure mode, in which the synergistic effects of the chemical agent and mechanical stresses result in cracking.
For more information, contact Scott Marko at smarko@4spe.org.

Thursday, February 18, 2016—*Jeffrey A. Jansen* – SpecialChem
DSC Interpretation Made Easy for Plastics Optimization—10:00 am EST
This webinar will help to boost your plastics developments by getting supportive data for performance optimization thanks to an extended use of Differential Scannng Calorimetry (DSC) analysis.
http://coatings.specialchem.com/online-course/1135-dsc-testing-polymers-plastics-characterization

Thursday, February 25, 2016—*Jeffrey A. Jansen* – AudioSolutionz
Understanding the Creep Behavior of Plastics—1:00 pm EST
The tendency of a polymeric material to deform permanently under constant pressure is known as creep. It happens over time through continuous exposure to stress levels that are under the yield strength of the material. Given sufficient time, it can cause creep rupture failure. When exposed to static stress, plastic materials, in particular, are prone to creep rupture. The relatively high rate of creep failure is because of the widespread lack of understanding and awareness of the effects of time on polymeric materials, especially at the design stage; the increasing use of plastic materials in diverse applications with longer time demands; and the unique difference in time dependence between polymeric materials and metals.
https://www.audiosolutionz.com/chemicals/creep-behavior-of-plastics-polymeric-materials.html

Thursdays, March 3, 10, and 17, 2016—*Jeffrey A. Jansen* - Society of Plastics Engineers
Understanding Failure of Plastics—11:00 am EST
The information presented in this **three-part** webinar will help the attendees understand how and why plastic components fail. The most efficient and effective approach to plastic component failure is by performing a systematic failure analysis following 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 and why a product has failed. This presentation will introduce the attendees to information needed to understand how this is done. The presentation will cover:

- The five factors effecting plastic part performance
- The primary plastic failure mechanisms
- Ductile-to-brittle transitions within plastic materials
- The process of conducting a failure investigation
- Failure analysis case studies

For more information, contact Scott Marko at smarko@4spe.org.

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

The Madison Group Adds Engineering Staff

Jack DeSousa Joins The Madison Group

Jackson DeSousa joined The Madison Group in August of 2015 after receiving his B.S. in Composite Materials Engineering from Winona State University. From his internship at Milwaukee Composites Inc., Jack gained valuable work experience in process optimization including mechanical testing and analysis, and thermoset resin chemistry. His responsibilities at The Madison Group include failure and design analysis of plastic, rubber, and composite parts.

William Aquite Joins The Madison Group

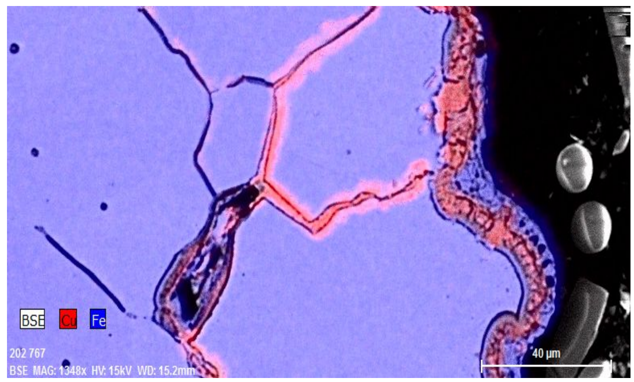
William Aquite received his B.S. in Chemical Engineering from the National University of Colombia and his M.S. and Ph.D. in Mechanical Engineering from the University of Wisconsin-Madison. His research work included characterization and simulation of extrusion flow and additive manufacturing techniques. During his graduate studies, he also served as Chief Engineer for the Polymer Engineering Center, President of the student chapter for the Society of Plastics Engineers, and as Ambassador for the Wisconsin Alumni Research Foundation (WARF) where he gained experience in patenting and licensing. His teaching experience includes assisting work for courses in composites (Introduction to Composites Processing) and polymer processing (Manufacturing Processes, Engineering Design with Polymers and Modeling and Simulation in Polymer Processing). Prior to joining The Madison Group, William lectured for core courses in mechanical engineering including Manufacturing Processes and Dynamic Systems. His training in polymer processing also includes field work at one of Dow Chemical's polystyrene plants and micro-injection molding research at the Institute of Plastics Processing (IKV) at RWTH University. He holds an appointment at the Grainger Institute for Engineering at University of Wisconsin-Madison, where he manages the facilities planning and leads collaborative efforts in the use of 3D printing for teaching and learning.

When Plastics Meet Metal *Guest Author: Rob Hutchinson*

Many products are now manufactured from a combination of both metal and plastic parts. If you are "of a certain age" you know that was not always the case. When plastics were first introduced they had few load bearing applications in engineered products. However, as a new family of material, plastics have been rapidly and dramatically developed, improving their strength, wear resistance and other industrially desirable characteristics. As a result, plastics now interface with metal components in applications that were once considered unfeasible.

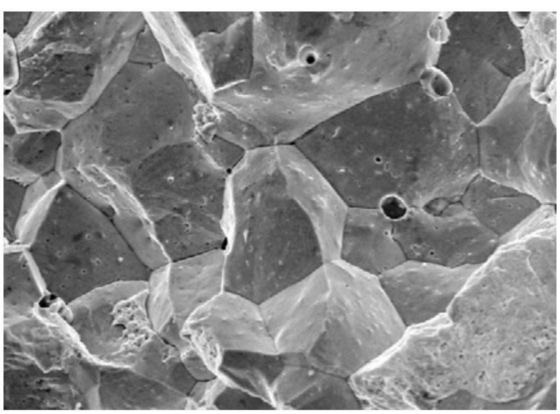
Most metals and metal alloys, on the other hand, are relatively mature materials. Recent improvements have resulted mainly from developments in processing that optimize their properties. However, new alloys continue to appear and hybrid materials, such as metal matrix composites have begun to enter the product stream.

Although we are materials engineers, Metallurgical Associates Inc. (MAI) works primarily in the field of metal's analysis and evaluation. Our work includes material, process and design evaluation. However, our primary focus is failure analysis and when this involves products assembled from both metal and polymer parts, our relationship with The Madison Group has been invaluable.



The client's goal for a failure analysis is prevention. Our goal is to meet that expectation by identifying remedies that prevent subsequent failures. These must be based on a scientifically valid evaluation and interpretation of evidence. The failure mechanism, characterized by its morphology, is an essential piece of evidence. However, identifying the mechanism does not reveal why the failure occurred. Brittle fracture, pitting corrosion or adhesive wear are end results, not the cause. Determining the cause requires data collection; chemical composition, physical properties, microstructure evaluation, manufacturing and service history.

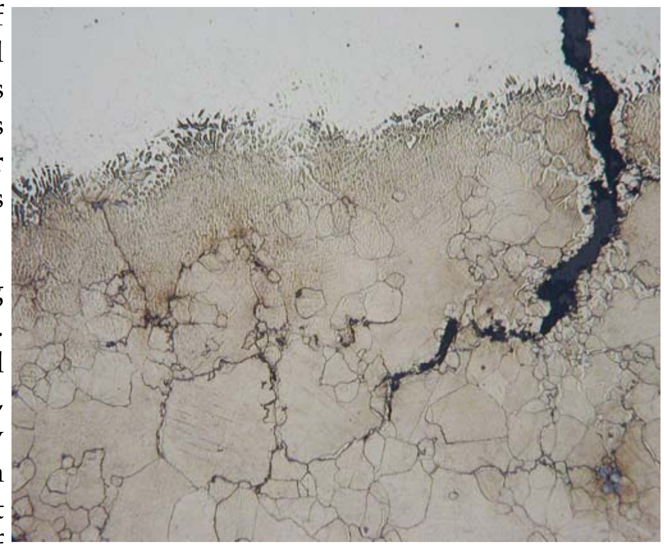
While many of the failure mechanisms that affect metals and polymers are similar, there are important distinctions, and their fracture features differ dramatically. Fractures in both materials are typically imaged and evaluated both optically and by scanning electron microscopy (SEM). Physical properties differ dramatically as well. The inner structure of plastics is made up of organic macromolecules that are more "mobile" than the relatively "rigid" atomic lattice structure of metals. As a result, most industrial metals exhibit physical properties of higher magnitude than plastics, such as hardness, tensile strength and wear resistance. Metals also maintain their physical properties over a wider temperature range.



Like some plastics, metals also have a crystalline structure, though in metallurgical nomenclature, these crystals are called grains and their interrelated arrangement is termed the grain structure, or microstructure. Metal grains have a defined interface with adjacent grains compared to the more interlaced nature of plastic macromolecules. This interface, or grain boundary, is critical to a variety of problems unique to metals. Severe service environments and faulty manufacturing processes can weaken the bond at the grain boundaries resulting in fracture. This can occur by a variety of mechanisms that plastics are not subject to, such as carbide precipitation, liquid metal embrittlement and hydrogen embrittlement.

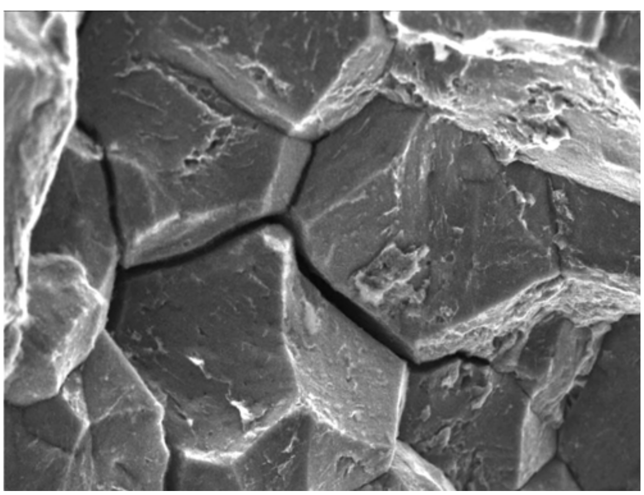
When Plastics Meet Metal (cont)

Microstructure evaluation is a major field in the analysis of metals that is less prevalent in plastics. The physical properties of metals can be varied by processes that modify the size, shape and chemical composition of the grains. These modifications in the grain structure, or microstructure, alter the physical properties of metals and are the basis of many manufacturing processes. Microstructure evaluation is performed by polishing and acid etching selected areas of interest. The etched sample is then examined by optical microscopy, which reveals characteristic features corresponding to the processes used in the components manufacture, as well as defects, inclusions and other aspects of the microstructure corresponding to the metals properties.



Heat treatment presents a substantial area of processing and analysis in metals that is not applied to plastics. Elevated temperatures generally degrade the physical properties of plastics. The physical properties of metals, however, can be beneficially modified and enhanced by controlled heating and cooling. Unlike plastics, which generally exhibit uniform properties throughout, heat treating can selectively modify the physical properties of metals at specific surface locations, leaving the properties of the substrate unchanged. This is the basis of case hardening and similar beneficial heat treating processes that produce a hard, wear resistant surface on a softer more flexible core. Heat treating processes come with their own set of potential problems. Quench cracking is the best known, and most prevalent of these, but is not the only consequence of improper heat treating procedures that can result in a component failure.

Metals are also joined and shaped by processes that are not available in plastics. While plastic parts can be joined in a variety of ways, these are typically bonding techniques which join two or more intact plastic surfaces. Metal parts are joined by a wide range of welding procedures in which the parts are locally heated past their melting point and fully fused together. Forging is another process applied to metals with no equivalent in plastic manufacturing. Using this technique, metal parts can be shaped into net or near net forms, by pressing or hammering, taking advantage of metals ability to yield, or permanently deform, and then be returned to its original, or even an improved state by heat treating.



Metals and plastics each offer unique, sometimes complimentary, and occasionally even overlapping service and manufacturing properties. Failures in these materials also range from unique material specific mechanisms to similar or analogous modes. The increasing use and interaction of both plastic and metal parts in products calls for specialized expertise from both material fields to optimize both their performance and economy.

To contact Metallurgical Associates, Inc. directly call 262-798-8098.

The Madison Group Teaches Failure Analysis, Design & Prevention Course

The University of Wisconsin—Milwaukee School of Continuing Education is offering a 3-day course entitled, **"Plastic Part Failure: Analysis, Design & Prevention"** taught by The Madison Group engineers Antoine Rios, Erik Foltz, Javier Cruz, and Jeffrey Jansen. The course will cover a broad range of topics essential to understanding and preventing plastic failure. Get introduced to the strategies behind analysis, design and prevention with course material that includes:

- Essential knowledge of why plastic components fail
- The five factors affecting plastic part performance: material, design, processing, installation, and service
- The process of conducting a failure investigation
- The importance of ductile-to-brittle transitions and their role in plastic component failure
- Methods for understanding how and why a product has failed
- Approaches to more quickly respond to and resolve plastic component failure
- Methods and techniques to avoid future failures
- Failure prevention through improved part and tool design

Course Outline:

- Overview of Plastic
- Composition
- Properties
- Plastic Part Failure
- Failure Correction and Prevention
  - Part Design
  - Mold Design
  - Material Selection
  - Processing
  - Validation Testing
- Failure of Plastics Overview
- Failure Mechanisms
- The Roles of Multiple Factor Concurrency and Statistical Distribution in Plastic Part Failure
- Failure Analysis
  - Problem Solving / Investigation Techniques – FA and RCA
  - Failure Analysis Test Methods
  - Case Studies

Plastic Part Failure: Analysis, Design & Prevention
Monday through Wednesday, **October 10-12, 2016**
8:00 am to 4:30 pm
Location: University of Wisconsin – Milwaukee
School of Continuing Education
CEUs: 2.0/PDHs: 20
Program No. 4830-8990

For more information, contact:
Murali Vedula, mvedula@uwm.edu, 414-227-3121

http://uwm.edu/sce/courses/plastic-part-failure-analysis-design-prevention/