TMG News

September 2016

The Madison Group
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Sectioning Techniques for Improved Part Analysis and Optimization

Dayton S. Ramirez, Dr. Javier Cruz, and Dr. Paul J. Gramann

Once a part is assembled and/or molded, the internal geometry, along with possible defects, may not be visible from an exterior examination. This can result in problems going undetected that may lead to poor performance and possible failures over time. Two essential techniques that are commonly used to fully analyze plastic parts/assemblies are computed tomography (CT) imaging and mechanical cross-sectioning. CT imaging is a non-destructive technique that creates a digital three-dimensional representation of the part/assembly. Whereas, mechanical cross-sectioning is destructive; requiring the part to be cut and polished at a predetermined plane. Each technique has its own advantages and disadvantages. However, both of these techniques allow the engineer to analyze, understand, optimize and prevent/fix failures that otherwise may go undetected.

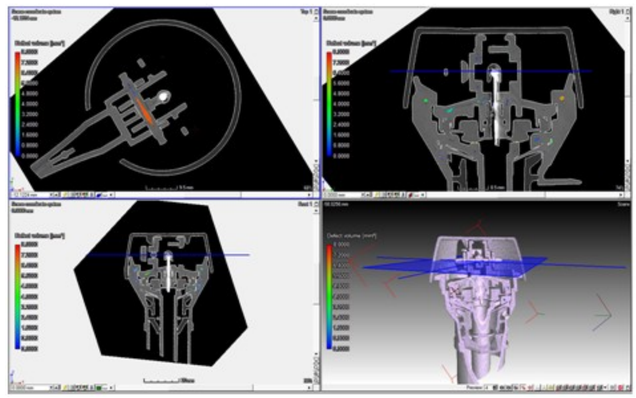

Figure 1: Two-dimensional views at multiple planes.

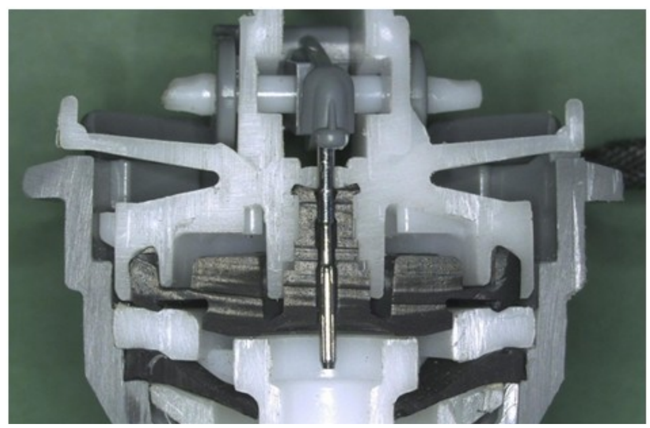

Figure 2: View of a cross-sectioned assembly.

CT imaging works by detecting differences in density between components that are being scanned. This technique generates multiple (typically 100s to 1000s per part) two-dimensional x-ray images that are digitally stitched together to produce a three-dimensional representation of the component or assembly. This allows an individual to examine the interior and exterior features of the part/assembly that may not be possible with basic visual analysis.

Using computer aided software; a user can scroll through multiple planes, angles and rotations to produce a two-dimensional sectional image anywhere throughout the part/assembly, Figure 1. Furthermore, with CT imaging, measurements can be taken, voids/cracks/misalignments can be detected and levels of porosity within a part can be quantified.

Mechanical cross-sectioning involves the physical cutting of a part/ assembly at a predetermined location; followed by a multi-step polishing process for the cut surface, Figure 2. To help support/lock components, the assembly can be mounted in epoxy before or after the cutting process; prior to the polishing step. The cutting process is obviously destructive, and will alter the current state and condition of the part/assembly.

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Typically, one or two cross-sections can be made from one part/assembly. Thus, the location of the interested plane is an extremely important step. Overall, the mechanical cross-section can often allow for a higher resolution inspection when compared to CT imaging, which allows for better detection of cracks and defects.

CT imaging and mechanical cross-sectioning are different techniques that can be used separately or in conjunction with one another. The most substantial difference between the two techniques is that CT imaging is non-destructive, while cross-sectioning is destructive. Therefore, if the part/assembly cannot be altered, CT imaging is the most viable option.

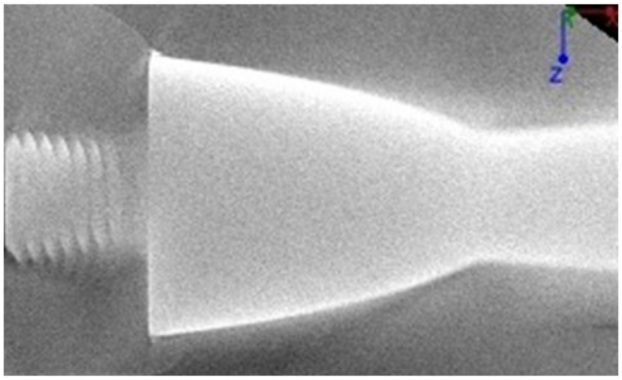

Figure 3: CT imaging showing a metal compo nent next to a polymeric, “sun halo” effect.

CT imaging comes with the disadvantage of producing grayscale images (the part color is lost). As stated, CT imaging distinguishes between differences in density. There are great advantages to this technique when analyzing polymeric or rubber components/assemblies. However, substantial differences in density can create issues, e.g. metal inserts in a plastic part. This combination can create a “sun halo” effect around the metal part, blurring-out possible areas of interest within the image, Figure 3. The grayscale imagery does not allow for clear examination of mixing, weld joints and knit lines. Mechanical cross-sectioning may be the preferred method when analyzing these processing-induced anomalies.

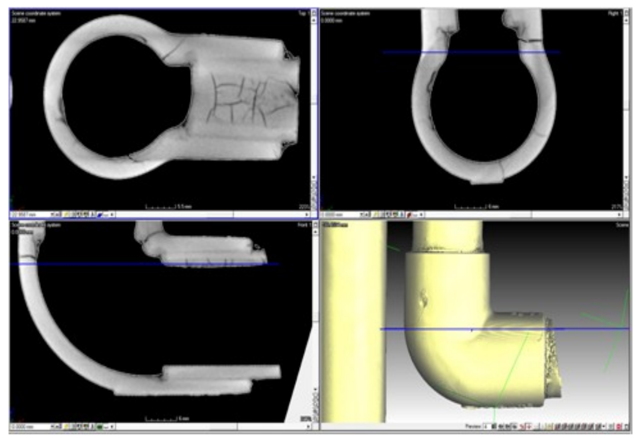

Figure 4: Imagery showing crack formation within a part.

When a fracture occurs in a part, the crack/puncture will create a void at the separation of the two surfaces, which will change the density in that area and make it visible, Figure 4. However, the separation of the two surfaces must be within the detection/resolution limit of the CT scanner being used. Depending on the part size and resolution of the CT imaging, the separation created by a hairline crack may or may not be visible. Overall, the resolution level will increase with decreasing the part size. CT resolution is best when analyzing a small part or region of interest. Big parts offer a higher degree of complexity/effort when conducting a mechanical cross-section. Therefore, a CT image can offer an alternative method to develop a cross-section regardless of the reduction in resolution.

The use of mechanical cross-sectioning allows for analysis of a single plane in the part. This works well if a crack, void or other anomaly crosses the sectioned plane. However, it is possible that anomalies are present away from the sectioned plane. This is where CT imaging is most powerful. It provides limitless digital cross-sectioning and allows the analyst to peer into the part at any location, angle/rotation or magnification (within the tolerance of the instrument). Therefore, the CT images can determine the precise location/plane of interest. At this point, CT imaging can be coupled with mechanical cross-sectioning. CT imaging can be used to select the location of interest that may not be readily visible on the part/assembly. Proceeding the CT analysis step, a mechanical cross-section can be performed to inspect the location of interest.

For more information, please contact Dayton Ramirez at 608-231-1907, or refer to the following article:

Cross-Sectioning as an Analysis Tool
http://www.madisongroup.com/publications/TMGNewsNovember2014.pdf

Upcoming Educational Webinars

Why Plastic Parts Fail: Plastic Failure Related to Multiple Factors - *Jeffrey A. Jansen*
Thursday, September 29, 2016
Time: Noon CST

Audio Solutionz

Often, in an event of failure of a plastic part, a tough question is raised – *Why is it that only a limited number of parts are failing?* This situation is particularly true when there are seemingly random failures at low, but significant failure rates. Such low failure rates often are brought out by two aspects: multiple factor concurrency, and the plastic failure's statistical nature. When two or more factors concurrently take place, failures are bound to happen, and in the absence of one of these factors, there is a considerably lesser chance of failure to occur.

If you are producing parts using plastic resins and associated forming processes, a statistical distribution of performance properties, strength and ductility are guaranteed. In the same manner, part stress, temperature and other environmental conditions also lead to statistical distribution, in which resin is exposed through its life cycle.

Failure occurs when the stress distribution on the part overlaps the part's strength distribution. Polymeric materials, are inherently subject to variability. This variation arises within the material from the molecular structure resulting from the polymerization process, and from the processes used to produce plastic parts. Most plastic failures occur when multiple factors overlap.
The general five factors influencing plastic part performance are:

- Material
- Design
- Processing
- Installation
- Service Conditions

https://www.audiosolutionz.com/chemicals/plastic-component-failure-rate.html

Plastic Failures Associated with Metal Fasteners— *Jeffrey A. Jansen*
Wednesday, October 5, 2016
Time: 10:00 CST

Society of Plastics Engineers

The need to secure plastic components is prevalent in the manufacture of assemblies in many industries. Joining plastic components to other plastic 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. This is because of the fundamental differences in physical properties, including strength, chemical resistance, and the 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. These cases depict representative failures involving varied designs and service conditions.

For more information, please contact Scott Marko at 203.740.5442.

Upcoming Educational Webinars

Reducing Environmental Stress Cracking in Plastic Parts—*Jeffrey A. Jansen*
Wednesday, October 19, 2016
Time: 9:00 am CST

SpecialChem

Reduce Environmental Stress Cracking (ESC) of your plastic parts by helping to predict failure occurrence and implementing adequate prevention measures. After reviewing **failure modes** and how to **predict failure** occurrence, **pragmatic prevention strategies** that are based on polymer selection, design and environment, will be discussed using real life case studies.

Approximately, 25% of plastic part failures in the industry are related to Environmental Stress Cracking (ESC). It is practically one of the **leading cause of failure**. ESC is often due to the combination of multiple factors (material, design, processing, and in-use).

1. Understand ESC's **underlying mechanisms** (ductile overload, creep model) and **factors affecting performance** (materials and design).
2. Help prevent ESC with **practical considerations** derived from Jeff Jansen's own experience (polymers, chemicals and situations with the highest risk)
3. Assess confidently whether your material is prone to ESC by using the **most suited test methods** (ASTM D543, ASTM D1693)

http://polymer-additives.specialchem.com/online-course/1154-escr-environmental-stress-cracking-plastics-failure-characterization

Understanding Fatigue of Plastics - *Jeffrey A. Jansen*
Thursday, October 20, 2016
Time: 10:00 am CST

Society of Plastics Engineers

The exposure of plastic materials to dynamic stress can produce several different responses, and will certainly alter the mechanical properties of the material. Fatigue is a very important failure mechanism for plastic components and a clear understanding of its implications is essential. Topics covered will include fatigue failure mechanisms for plastics, factors effecting fatigue resistance, and fatigue testing. The effects of fatigue loading will be reviewed, and a case study will be used to illustrate failure resulting from dynamic stress loading.

For more information, please contact Scott Marko at 203.740.5442.

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

From the TMG Solutions Archives:

Knitline Failure Analysis

Keywords - Failure, Cross-Sectioning, Knitline and Polypropylene

What Went Wrong?

An injection molded polypropylene part used in a conveyor application was experiencing cracking near the knitline of parts produced from a gray masterbatch resin. No cracking was observed in similar parts produced from a pre-compounded gray resin. All parts were manufactured in the same press/tool and similar process parameters were used for each resin type.

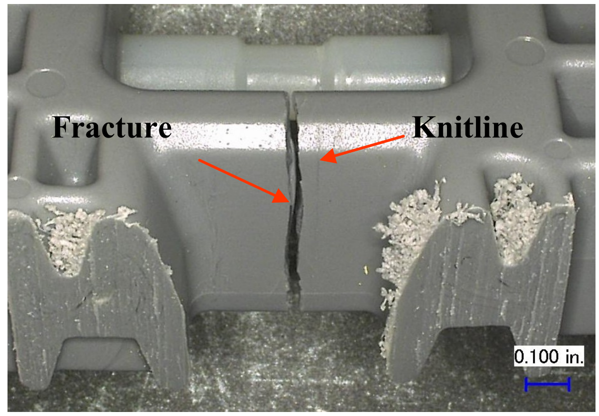

Figure 1: View of the fracture location in the part produced from a gray masterbatch resin.

Evaluation

A microscopic examination of the fracture site in the failed component revealed that the crack was parallel to, but slightly offset from the visible knitline on the outer surface of the part, Figure 1. Inspection of the fracture surface showed the presence of a large internal void running through the mid-wall of the knit line region, Figure 2. Multiple crack initiation sites were observed extending from the edges of the void. The initiation sites showed features representative of a brittle, slow crack growth failure mechanism over time that was consistent with creep rupture. Thus, the crack developed within the part and propagated outward during use.

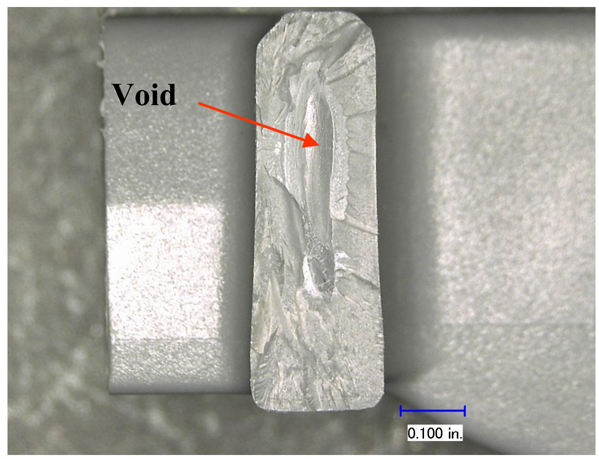

Figure 2: Micrograph view of the fracture surface of the failed part showing the presence of a large internal void at the approximate knitline location.

Polished cross-sections were prepared through the knitline regions of reference parts produced using the pre-compounded gray resin and the masterbatch gray resin, as shown in Figure 3. The distribution/mixing of the colorant in the pre-compounded resin component was excellent, while pigment streaking was readily apparent in the masterbatch resin component. Additionally, excellent knitline fusion was visible in the pre-compounded resin component, while the masterbatch resin component displayed a similar internal void at the knitline as the failed part.

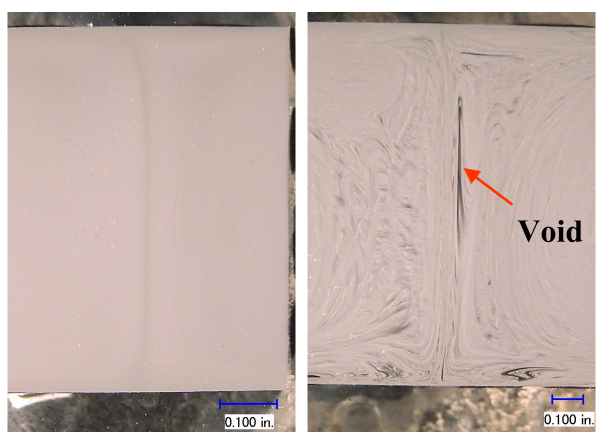

Figure 3: Micrograph views of polished cross-sections through the knit line regions of a part produced from a pre-compounded gray resin (left) and a masterbatch gray resin (right) showing poor mixing and an internal void at the knitline of the masterbatch gray part.

Conclusion

It was the conclusion of the evaluation that the conveyor component failed as a result of voids within a poorly fused knitline. Inadequate mixing of the masterbatch resin during molding appears to have created differing flow and shrinkage properties in the masterbatch resin, which led to the weak knitline when processed in a similar manner to the pre-compounded resin.

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The Madison Group Teaches Failure Analysis, Design & Prevention

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 Dr. Antoine Rios, Erik Foltz, Dr. Javier Cruz, and Jeffrey Jansen. The course will cover a broad range of topics essential to understanding and preventing plastic failure. Become 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
- Process of conducting a failure investigation
- 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 quickly respond to and resolve plastic component failure
- Techniques and methods 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. 4830-7956

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

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

UWM

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

Announcements:

The Madison Group Adds Engineering Staff

John Nebbia Joins The Madison Group

John joined The Madison Group in June of 2016 after graduating from Winona State University with a B.S. in Composite Materials Engineering and a minor in Mathematics. Before joining The Madison Group, John worked at the Composite Materials Technology Center (COMTEC) performing thermal and mechanical testing of polymeric materials.

Additionally, John has worked in different manufacturing engineering positions with Coda Composites and Abrasive Technology. While working at these companies, he implemented continual process improvement, worked in new product development, and conducted research.

At The Madison Group, his work primarily involves material evaluation, failure analysis, and prevention. John is also an active member of the Society of Plastics Engineers (SPE).

Remembering Dr. Myer Ezrin Dr. Paul J. Gramann

It is with great sadness that I write this article on the passing of a dear friend and mentor.

Dr. Myer Ezrin, known as Mike to the many friends he had, passed away on May 6 at the age of 89. Mike was an icon in the plastic failure and prevention community. He was an icon not only because of his in-depth knowledge, but because of his great passion for the subject and his willingness to educate any person that asked.

I recall, as a young engineer, timidly calling Mike to educate me on thermal desorption gas chromatography/mass spectroscopy. Nearly two hours later with my head full and spinning, I had a clear direction on how to proceed with the project I was working on. More importantly, I made a new friend that would last for almost two decades. He made it clear that I could call him at anytime to discuss plastic failure, prevention, testing and life in general – I took him up on this generous offer many times.

These discussions will be **truly missed.**