September 2018

TMG News

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25 Years Anniversary

PLASTIC CONSULTING ENGINEERS THE MADISON GROUP

Additive Manufacturing - Applications on the Production Floor

William Aquite, Ph.D.

Additive Manufacturing, commonly referred as 3D printing, is now beyond a trending topic. Multiple industries have seen it as a practical solution for design challenges and as a tool for innovation. Yet, despite the advantages offered by additive manufacturing (AM), it has not yet made it to all production floors. Transitioning from conventional manufacturing processes to the use of an AM process may represent a costly investment and a risky business venture that may not render the former product properties. However, AM technologies, when applied appropriately, provide an alternative solution to reduce production costs and improve operational times. This article discusses an application through which, manufacturers take advantage of this disruptive manufacturing trend; the manufacture of molds for injection molding processes.

Additive manufacturing works by building a part layer by layer from a digital model. This offers the opportunity to realize unique designs that may include intricate details. In the past decade, AM has benefited from advancements in computing power, design software, material availability and automation, which have brought this technology to the everyday consumer. A variety of AM processes, materials and resources are readily available for the design and manufacture of parts in ways that were never before possible. Also, technology development continues to decrease the cost and increase the variety of applications for AM.

Although there are many manufacturers experimenting with AM, not all can implement it for production. Cost, material availability and data, production volume capability, and the inherent complexity of implementing a new design and production paradigm, represent limiting factors for businesses to take up AM. For others, they may have existing processes that are perfectly suitable for their business. Nevertheless, the versatility of AM technologies can still be implemented for practical and efficient solutions on the production floor. This article focuses on the use of AM for the manufacture of plastic molds for injection molding processes.

AM processes are used to replace manufacturing tools with lightweight equivalents. This application, often referred to as *additive tooling*, enables the production of jigs, fixtures, gauges, patterns, as well as dies and molds. Additive tooling is applicable to many industries considering the low volume and customized, complex designs of manufacturing tools. Furthermore, it can be easier and faster to implement. Due to their specialized level of application, these tools often require a higher degree of customization and accuracy that usually translates to increased costs and longer lead times. The manufacturing of tools via AM allows manufacturers to restructure and modernize production processes by customizing and making components according to a particular on-demand need. This reduces the tool fabrication expense by reducing labor and accelerating product delivery.

Injection molding molds are conventionally manufactured in CNC (Computer Numerical Control) machines using materials such as steel or

Inside This Issue:

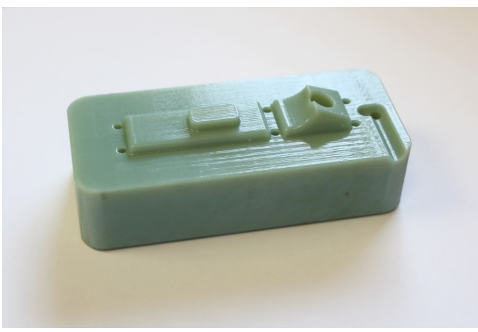
Additive Manufacturing - Applications on the Production Floor (cont.)

William Aquite, Ph.

aluminum. The ever-growing catalog of materials in AM offers specialty materials with high temperature resistance, stiffness and toughness that make them suitable for the production of short-run molds.

AM Metal Molds for Injection Molding

Metal molds are typically manufactured using a suite of traditional machining methods to achieve tolerance requirements and use materials such as aluminum and steel to withstand the high pressure and temperatures during the injection molding cycles. The feasibility of manufacturing molds for injection molding (IM) applications are possible due to the technological advancements in AM, along with the availability of materials with high temperature resistance and stiffness. AM injection molding molds may reduce the costly investment for a metal mold by 40 to 80 percent. Additionally, AM plastic molds are lighter and can be produced with shorter lead times (1-2 weeks) than metal molds (5-7 weeks). Lightweight tools may also boost efficiency by simplifying assembly operations. A reduction in labor and accelerated delivery of parts could result in higher profits for businesses.



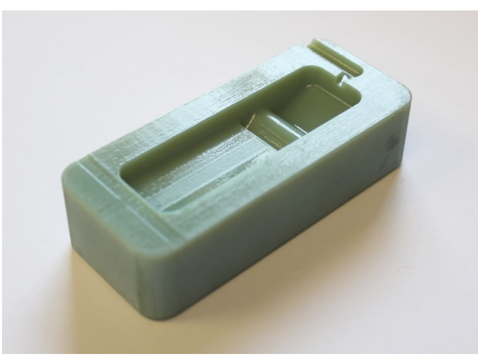


Figure 3: *Injection molding mold manufactured with a Material Jetting process using Digital ABS material. Courtesy of Steinwall Inc.*

The use of AM for the production of IM molds is currently limited to low-run injection molds and as a tool for mold design verification. Restrictions on mold design (draft angles, ribs and gussets, wall thickness and split lines) are dependent upon the injection molding equipment and on the AM process of choice. Processes such as *Material Jetting* and *Vat Photopolymerization* are suited for printing of pieces with smoother surface finishes and a higher level of dimensional accuracy, and have proven to be successful for many producers, **Figure 3**. The surface quality rendered by these processes reduces the amount of post-processing and allows for the manufacture of parts with complex designs that include thin features. Part volume represents an additional design limitation. IM parts manufactured with these processes are limited to 10 cubic inches. Nevertheless, low-volume production or prototyping is advantageous for the identification of flaws associated with the IM process; the part geometry and the material of choice. It may also represent cost reduction in small production runs. While the thermal temperatures profile may be significantly different than in traditional molds, the efficiency of a cycle could be optimized by designing unique cooling configurations into the AM molds.

The product quality, as well as the integrity of the AM mold, can be affected by the continuous exposure to compressive loading and heat during the injection molding cycle. This is why AM molds are recommended for production volumes between 10-100 parts. The performance of an AM mold will depend on the melt temperature of the injection material, the part geometry, and the injection molding process parameters. Material properties such as thermal expansion, tensile modulus and strength at elevated temperatures are relevant in the manufacturing of molds for IM (e.g., A material with relative high stiffness will prevent

Additive Manufacturing - Applications on the Production Floor (cont.)

William Aquite, Ph.

deformation of the mold during the removal of a part.) AM molds are often mounted in metal frames to provide support against the pressure and heat the mold is subjected to during the IM cycle. Further support could be given by embedding reinforcement structures into the mold. This may also aid in preventing warpage of the mold and depending on the reinforcement material, the improvement in the cooling time during the IM cycle.

Although the investment in AM technologies may require additional training and modifications to the supply chain, and the technologies cannot yet outmatch traditional manufacturing techniques for mass production, businesses continue to implement AM to find solutions that provide an economic advantage in manufacturing. The versatility offered by the AM technologies could be used to aid and increase efficiency in injection molding processes. IM molds are only one of the examples where AM offers an alternative for low volume production of products with complex designs that is compatible with a conventional manufacturing process.

Vat Photopolymerization

In this process, the surface of a liquid photopolymer is exposed to a light source (LED or UV) that cures and solidifies it at a specific depth. Then, the platform that holds the part moves and the next layer of material is then allowed to cure and bond to the previous layer. The most common vat photopolymerization processes are Stereolithography (SLA) and Direct Light Processing (DLP). The resulting parts are chemically bonded as such that they are fully dense and isotropic.

Part design for vat photopolymerization processes needs to consider the inclusion of support structures for overhanging and bridge features. Post-processing operations for this process include the manual removal of these support structures and additional sanding to remove any marks left after their removal.

Resolution | 0.025 – 0.15 mm
Accuracy | ± 0.01 - 0.03 mm
Volume | 150 x 150 x 175 mm – 1500 x 750 x 500 mm

Material Jetting

In this process, droplets of liquid photopolymers are deposited using a piezo-electric printing head. As the material is deposited, it is instantly cured by exposure to UV light. Material jetting produces parts at a relatively faster way than other AM processes.

Support structures for this process can be printed with a different material that can easily be broken off the part. However, dissolvable resins are also available. The support material is deposited through a secondary nozzle and is removed during post-processing.

Resolution | 0.016 – 0.032 mm
Accuracy | ±0.05 mm
Volume | 380 x 250 x 200 mm – 1000 x 800 x 500 mm

Information regarding additional case studies can also be found at:
https://www.madisongroup.com/case-studies.html

The Power of Cross-Sectioning

John R. Nebbia

Overview

Cross-Sectioning is a valuable resource in an engineer's toolbox. It allows for examination of features or defects within the thickness of a part. The part can either be cross-sectioned in its current state or potted in epoxy to minimize the risk of components or contaminates moving during examination. This article will examine some common features that can easily be exposed and studied via cross-sectioning.

Applications

Thickness Verification: Cross-sections can be taken of molded parts, and their wall thicknesses can be measured microscopically or mechanically, in order to verify a wall thickness distribution has been met. This technique is valuable with injection-molded parts. It has also been proven to be a valuable method for various manufacturing techniques, such as blow molding, where the thickness distribution is not as easily controlled.

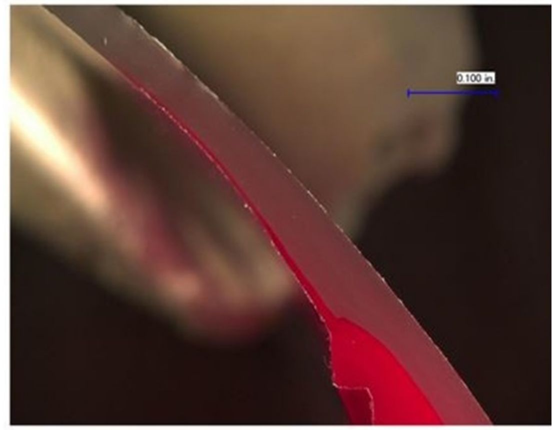


Figure 1: *Micrograph view of a two shot part in which, too much shear heating caused the first shot (Red) to melt and wash into the second shot (Clear), as the second shot was being injected.*

Laminar Behavior and Inter-Facial Effects: In injection molding, there is always a surface interaction between the polymer melt and the material it is flowing across, such as the mold steel or first shot. When a sample is cross-sectioned, this interaction can be studied, which often answers simple questions such as: Was the mold temperature too cold? Was too much shear heat produced? Having too cold of a mold will often lead to a visible skin-core effect. Having too much shear heat in a multi-shot molding process can result in melting and washing of the first shot, **Figure 1.**

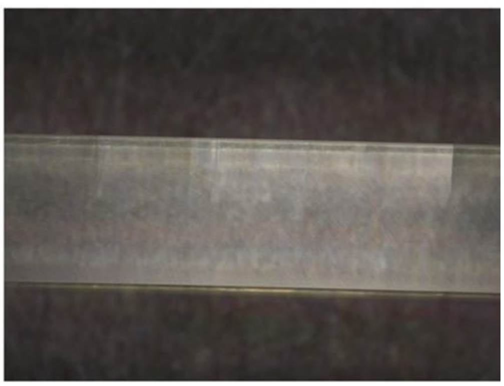


Figure 2: *A cross-section was taken of a polycarbonate specimen that had been exposed to isopropyl alcohol while under stress. This allowed for examination of the cracks and their depth in the sample.*

Diffusion and Environmental Stress Cracking: Cross-sectioning can be a useful tool to identify early-stage cracking in a component or to view a chemical agent that has diffused into a sample, **Figure 2.**

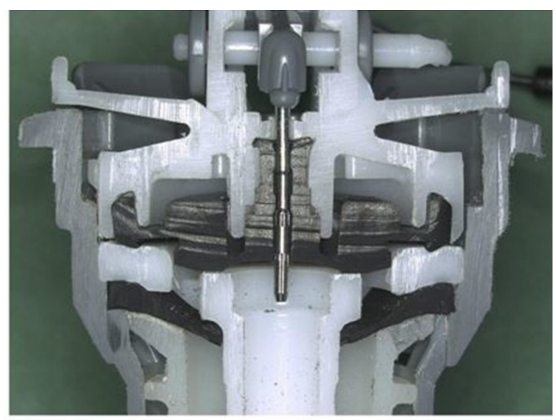


Figure 3: *A cross-section showing the multiple components in a valve. This ultimately allowed for a thorough understanding of the interaction between the components in this assembly.*

Component Assemblies and Welded Joints: One of the most common uses of cross sectioning is to examine an assembly. How do two sub-components fit, function or interact together, **Figure 3.** Further, cross-sectioning can also be used to examine the integrity of welded joints in an assembled part.

Contaminants: Often times particulates can make it into an injection-molded part. These materials can act as a contaminant, and can weaken the part on both a mechanical and/or molecular level. Cross-sectioning can act as a means to view these encapsulated particles.

Information regarding additional case studies can also be found at:
https://www.madisongroup.com/case-studies.html

Upcoming Educational Seminars—Free of Charge—Two Locations

How to Optimize Your Mold Cooling to Drive Down Costs and Drive-Up Part Performance

Wednesday– September 12th, 2018
Waukesha County Technical College - Waukesha, Wisconsin
9:00-12:20: Presentation/ 12:30-1:30: Tour of WCTC Plastics Facility

- **How your Cooling Line Layout and Mold Design Are Influencing Your Part Cost and Performance**

Erik Foltz
The Madison Group

- **Why You Should Consider High Temperature Water Cooling Units**

Dan Luke
Norstech

- **The Effect of Glass Fiber Length on the Short-term and Long-Term Behavior of Polypropylene**

Dayton Ramirez
The Madison Group

Tuesday – September 18th, 2018
University of Wisconsin – Stout - Menomonie, Wisconsin
9:00-12:20: Presentation/ 12:30-1:30: Tour of UW-Stout Plastics Facility

- **How your Cooling Line Layout and Mold Design Are Influencing Your Part Cost and Performance**

Erik Foltz
The Madison Group

- **Why You Should Consider High Temperature Water Cooling Units**

Dan Luke
Norstech

- **Going Beyond Single Point Measurement:**
  Practical Uses of IR Cameras and DMA Data to Optimize and Troubleshoot Your Mold

Sean Mertes
AMCO Polymers

For more information, please go to our website: https://www.madisongroup.com/events.html.

To register for each seminar, please email: Events@madisongroup.com

Educational Outreach Sponsored by:

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

Upcoming Educational Webinars

Webinars provide a cost-effective way to expand your knowledge of plastics.

Below is a list of the upcoming webinar presented by TMG Engineers:

Thursday, October 4, 2018—*Jeffrey A. Jansen*– Omnexus by SpecialChem
Plastics: The Correlation of Molecular Structure and Performance

Gain a much better understanding of how the performance properties of plastics are tied directly to the molecular structure of the polymer. Attendees will see how different aspects of the structure alter the physical properties of materials, including mechanical, thermal, chemical resistance, and environmental.

This webinar will cover a wide range of thermoplastic materials. Because structure is important to all thermoplastics, it will address aspects ranging from simple structures such as polyethylene to the more complex such as polyesters, sulfones, and polyaryletherketones.

Registration Information Coming Soon!

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

Announcements:

Paul Gramann, August 2018

The Madison Group Turns 25

It was during the summer of 1993 that my colleague Bruce Davis, our advisor Prof. Tim Osswald and I sat down together to discuss a crazy idea of forming a company to transfer knowledge to the plastics industry. At that point we knew there was a need. We already had clients with whom we worked on consulting projects and more importantly, we had the backings of our wives. We were graduate students, therefore, we were used to working long hours for very little. Most importantly, we were naive enough to think we could pull it off. Thus, on August 13, 1993, The Madison Group was officially formed – the name coming from being known as the "Madison Guys."

The decision to start a new company was surprisingly easy considering that both Bruce and I already had job offers from Fortune 500 companies; Caterpillar for Bruce and 3M for me. Our first "office" consisted of a dedicated telephone line and answering machine in my basement, and a fax number sent to the modem on Bruce's computer at home. We sent out press releases to all the plastic's magazines describing a software product that we had developed to simulate the compression molding of plastics. After waiting weeks to see the red light blinking on that answering machine, we finally received a message from Rockwell, followed shortly thereafter by one from Square D.

Like many new startups, we also faced challenging times. During our early years, we resorted to creative ways to make ends meet – such as selling German chocolate eggs and packaging/mailing diskettes for a plastics database. Over time, our hard work and dedication to excellence paid off as we gained the trust of companies, and The Madison Group became an integral part of many engineering departments. Over the next 20 years, The Madison Group grew steadily and that required relocation to larger office facilities five times over those first two decades. This growth was driven, in no small part, by the incredible engineers and office staff that made-up The Madison Group team. Four years ago, the partners made the bold decision to build a corporate headquarters/laboratory, thus establishing a solid foundation from which The Madison Group could continue to grow.

(**Front row**) Antoine Rios, Paul Gramann, Amy Bembenek, Patrick Mabry, Dayton Ramirez, and Richie Anfinsen.

(**Back row**) John Nebbia, Jack DeSousa, Jeff Jansen, Javier Cruz, William Aquite, Erik Foltz, and Bruce Davis.

The Madison Group would not have grown to what it is today without the outstanding team who is dedicated to solve our clients' challenges and problems.

The Madison Group—New Corporate Building

Today, The Madison Group is poised to grow into the next 25 years with its incredible staff of engineers: Richie Anfinsen, Dayton Ramirez, William Aquite, Jack DeSousa, John Nebbia and Patrick Mabry, its partners Paul Gramann, Bruce Davis, Antoine Rios, Erik Foltz, Javier Cruz and Jeff Jansen, and the best office manager on the planet; Amy Bembenek.

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 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:

- Learn the essentials of why plastic components fail
- Understand the five factors affecting plastic part performance
  - Material, design, processing, installation, and service
- Learn the process of conducting a failure investigation
- Know the importance of ductile-to-brittle transitions and their role in plastic component failure
- Understand how and why a product has failed
- Explore approaches to more quickly respond to and resolve plastic component failure
- Learn methods and techniques to avoid future failures

Course Outline:

- **Introduction to Plastics**
  - -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

in

Plastic Part Failure: Analysis, Design & Prevention
Monday through Wednesday, October 15-17, 2018
8:00 am to 4:30 pm
Note: Class ends at 4:30 pm on Days 1 and 2
Class ends at 3:00 pm on Day 3
Location: University of Wisconsin – Milwaukee School of Continuing Education
CEUs: 2.0/PDHs: 20
Program No. 4830-10835

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