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- Low moisture absorption
  Cured laminates retain less moisture, reducing risk of porosity in parts.

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**BENEFITS**

- Matched CTE
  Composite molds match tool and part CTE, improving part accuracy.

- Lower thermal mass than metal tools
  Allows faster heat up, shorter cures & greater productivity.

- Excellent adhesion
  Can also be used for reinforcing Airpad Rubber tooling.

Built in 1987 and has manufactured over 900 parts.

LTC

**BENEFITS**

- Low initial cure temperature
  Reduces thermal expansion of master model, improving mold accuracy.

- Cost effective option
  Lower cost, low temperature master model materials can be used.

- Excellent laminate quality
  Good surface finish and low void content produces longer life molds.

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Built in 1987 and has manufactured over 900 parts.
Dear Members

This is my last Global Presidential message, as my mandate ends at the end of June, and a new Global president (much better than me) will be in charge.

It seem to me that this year has flown away fast. I still remember my first message and the feelings that I had about my contribution to this society; since then, almost a year has passed and now I am here writing my farewell message.

It has been a very fruitful year for me as your SAMPE Global President. I have had the privilege to contribute to many changes in the Society. The reorganization of SAMPE and the transition to a Global Society took place just four years ago, so it is natural that the first years are “assessment” years in which everything is continuously under test and the mechanisms are not fully automatic.

Therefore, in every Board meeting that I have participated, I have assisted to progress toward a better organization of SAMPE Global. In particular, two things that I consider very important have happened during this period: the official entry of China as a Region, and the introduction of the new logos. Both events were prepared when I was Vice President, but I had the luck to be President when they become a reality.

Having China as a new region has allowed SAMPE to reach fully global status, and our friends from China are now completely established in our society and their regional activities are increasing their international audiences.

The new logo had its debut in Paris this year. I was very curious to see how it looked printed on the signs and on the proceedings. I also wanted to know the opinion of the people attending the SAMPE Europe Summit. Well, I have to say that most of the people liked it, and those who did not were few. I hope that also in the other regions our new logo will be accepted and will become soon familiar.

Other changes are going to take place soon; one will concern this Journal as we are working to make it meet the needs of our members and sponsors with more scientific and technical contributions and less presidential talks such as this.

Before I finish this last message, let me mention and thank all the people that I have been working with during this last year. First of all, the entire SAMPE staff—all great friends and great workers. Then the Global Cabinet and the Global Board, I have been happy to share this time with you my friends. I must also mention Gregg and his efficiency and friendship. And, last but not least, all of you that support our society. It has been an honor for me to contribute to the progress of SAMPE Global and I will continue to do it as a Past President.

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Centennial celebrations don’t come very often – only once every 100 years. But when they do, there often is a lot of technological progress to celebrate. As SAMPE approaches its 75th anniversary as a Society in 2019, we can look at the Air Force Research Laboratory (AFRL) and the Boeing Company as they celebrate their 100th anniversaries this year. SAMPE has focused on a depth of material advancement and process engineering technologies. AFRL and Boeing have also focused on these same areas – with considerable interaction between all three entities. In fact, many of the technology advancements have come from the people of all three entities teaming together on moving critical technology forward over the past 100 years.

AFRL has its roots in Dayton, OH at a place close to where the Wright Brothers created early aviation history in their shop. McCook Field, an early Army Aviation location, became the home of the Materials and Manufacturing Directorate for what later would be the foundation of AFRL. AFRL has been the key and foundation for numerous “materials” advances” and “manufacturing technology growth” for advanced materials technologies and process engineering during the 1917-2017 period. Technologies associated with metals, metallurgy, polymers, ceramics, various composites, fiber reinforcements, high temperature materials, sensors and smart technology, nanotechnology, design and analysis methodologies, and, numerous other “leading edge technologies” in support of SAMPE’s mission.

AFRL, however, has provided much more than technology, materials and processing. From SAMPE’s earliest days, AFRL has provided SAMPE with the essence of its treasure in the contribution of its manpower and technologists over the past 70+ years. AFRL personnel are highly active in supporting major SAMPE events and have volunteered to serve SAMPE leadership roles. Additionally, AFRL staff have been acknowledged as SAMPE Fellows, Lubin Award winners, and Mort Kushner winners.

The Boeing Company also had its roots in 1917 and is currently the world’s largest aerospace company and leading manufacturer of commercial jetliners and defense, space and security systems. As America’s biggest manufacturing exporter, the company supports airlines and U.S. and allied government customers in more than 150 countries. Boeing products and tailored services include commercial and military aircraft, satellites, weapons, electronic and defense systems, launch systems, advanced information and communication systems, and performance-based logistics and training. Materials advancements and process engineering applications have been adapted in Boeing’s numerous products that we currently see every day.

Boeing has a long tradition of aerospace leadership and innovation. The company continues to expand its product line and services to meet emerging customer needs. Its broad range of capabilities includes creating new, more efficient members of its commercial airplane family; designing, building and integrating military platforms and defense systems; creating advanced technology solutions; and arranging innovative customer-financing options.

Similar to the AFRL, Boeing staff have and continue to serve on many task forces, committees and projects. Boeing’s SAMPE members have played (and continue to assume) key leadership roles with SAMPE. And, you will find Boeing engineers as SAMPE Fellows, Kushner and Lubin Award recipients.

The partnership SAMPE has with the AFRL and Boeing has contributed to advancing the knowledge and applications of advanced material technologies both of these renowned organizations have and continue to share and contribute to SAMPE and for this we are a stronger, better engineering society.

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Evaluation of RTM370 Polyimide Composites by Resin Film Infusion (RFI)

Abstract

RTM370 imide oligomer based on 2,3,3’,4’-biphenyl dianhydride (a-BPDA), 3,4’-oxydianiline (3,4’-ODA) and terminated with the 4-phenylethynylphthalic (PEPA) endcap has been shown to exhibit a low melt viscosity (10-30 poise) at 280°C with a pot-life of 1-2 h and a high cured glass-transition temperature (Tg) of 370°C. RTM370 resin has been successfully infused into fiberglass-stitched T650-35 carbon-fabric preforms (ranged from 3- to 6-mm thick) by resin film infusion (RFI). The resulting composite panels were inspected by ultrasonic C-scan and by photomicrographs before and after post-curing as a quality control. Mechanical tests such as un-notched compression (UNC), open-hole compression (OHC), and short-beam shear strength (SBS) at ambient and elevated temperatures were performed before and after isothermal aging at 288°C for 1000 h to assess high-temperature performance. Thermal cycling of RTM370 stitched composites was also conducted from -54°C to 288°C for up to 1600 cycles to evaluate the microcrack resistance of RTM370 polyimide composites fabricated by RFI.

Introduction

Resin film infusion (RFI), developed initially by Boeing, is a relative new technique to fabricate polymer-matrix composites without the use of carbon-fiber prepregs impregnated with resins and, often, with solvents. A resin as a film is placed on top or underneath a fibrous preform, tooling is located, and the assembly is enclosed with a vacuum bag through which the vacuum is applied. As the temperature rises in the autoclave, the resin film melts and infuses into the laminates beneath under the combined pressure gradient of the vacuum and autoclave pressure. The assembly is then cured into composites at elevated temperature. The advantages of RFI include: 1) Ability to produce composites with high fiber-to-resin ratio and low void content. 2) Environmental friendly without volatiles. 3) Capability to fabricate large components with minimum workforce. Numerous epoxies and bismaleimides (BMI) resins have been fabricated by RFI into high-quality composites and aircraft parts in the aerospace field. However, the performance of epoxy and BMI are limited to 177°C and 232°C use temperatures, respectively. Boeing has conducted RFI using newly developed low-melt-viscosity, imidized oligomers, such as PETI-3306 or RTM370, in order raise the higher temperature capability of composites for aircraft applications.

This paper presents an evaluation of RTM370 polyimide composites, fabricated with fiberglass stitched T650-35 fabric preforms (ranged from 3- to 6-mm thick) by resin film infusion (RFI), for potential airframe application. Mechanical properties were conducted from room temperature to 288°C (550°F). Additionally, mechanical properties after isothermal aging at 288°C for 1000 h and microcrack resistance after thermal cycling from -53°C to 288°C will be discussed.

Figure 1. Solvent-free preparation of RTM370 imide oligomers.
Impact of HP-RTM Process Parameters on Mechanical Properties with Epoxy and Polyurethane Systems

Abstract
High pressure resin transfer molding is a method for processing continuous fiber reinforced composites at industrial production rates. This paper examines the more common HP-IRTM variant, where the ‘I’ stands for injection. To achieve a composite with the best mechanical properties, a combination of the fiber, resin and processing parameters must be understood. Two different matrix materials, epoxy and polyurethane, and two different fibers, glass and carbon, are processed on a KraussMaffei HP-RTM system at the Fraunhofer Project Center in London, Ontario, Canada. Several processing parameters are investigated during the manufacturing of these polymer matrix composites including the press force during injection, the press force during cure, and the injection rate. Subsequently, the manufactured parts are characterized and their mechanical properties are evaluated. The results of this study shed light on the critical properties and process settings in HP-RTM production.

Background
The effective use of composite materials in structural automotive applications requires robust understanding of process-property relationships. One major technology used to manufacture structural parts is high-pressure resin transfer molding (HP-RTM) as it utilizes continuous fibers in a stitched or woven fabric form.

Resin transfer molding has long been used to create structural composites. The main drawback of the process is the long infusion time coupled with a slow cure reaction. Recently, high-pressure infusion has been tested as a method to dramatically reduce the cycle time, as reported1,2. These past studies have examined the different process variants and the effect of pressure on the resulting quality of the produced material.

This paper continues the study of the injection variant of high pressure resin transfer molding process by examining some of the influences of the processing conditions on the composite mechanical properties. Two of the most common matrix materials, epoxy and polyurethane, are compared in a parametric study of the main processing parameters: the injection rate, the press force during injection, and the press force during cure.

To manufacture the samples, a new KraussMaffei Rimstar 8/4/8 high-pressure RTM system at Fraunhofer Project Centre (FPC) was used. In this study 20, 40 and 60 g/s injection flow rates used were used, while the press forces were varied between 1000-5000kN. The nominal part thickness was 2.3 mm, while the fiber volume fraction was set to a target value of 60%.

The results of this study shed light on the critical forming properties and process settings required to attain the peak performance. The influence of processing parameters on the material properties were determined with this study.

Experimental Setup
The process flow of the high-pressure injection RTM (HP-IRTM) is similar to the standard RTM process. The main difference is injection of material system at high pressure within a short period of time. The high-pressure injection thus implies that a significant amount of force is required to maintain the mold closed. In this process, the mold remains completely closed before the injection starts, thus defining the fiber volume content and the final part thickness. A preform is placed into mold before closing. The major impregnation of the preform is in the direction of width and length (x-y axis) and should be completed before the reactive resin starts to cure. A vacuum unit can be connected to the mold to further improve the part quality and to reduce the amount of voids3. The main process steps of the HP-IRTM cycle are shown in Figure 1.

The main advantage of HP-IRTM, compared to the standard RTM process, is the ability to use fast curing resin systems. This is particularly needed for high volume productions of automotive parts. However, high injection-pressure and high flow rates can lead to “fiber-
Integration of Composite Part Design and Processing Simulation in Liquid Composite Molding (LCM)

Abstract

In Liquid Composite Molding (LCM) processes, processing simulations are necessary to virtually execute the manufacturing steps to verify the design. Processing parameters, such as infusion/venting plan, should be optimized and the process simulation results should provide accurate feedback to designers suggesting necessary design modifications. It is highly desirable to couple the manufacturing process design with the part design cycle, so that the designer can modify the part to meet the design requirements, include manufacturing constraints and maximize part yield simultaneously. However, the inherent material variability and geometry features designed for mechanical requirements may introduce processing variations (for example flow disturbances) that introduce variability in the manufacturing process and require hundreds of simulations to capture the effect of the stochastic nature. This also requires large amount of highly specialized pre-and post-processing analysis and consequently, it prevents the designers from using processing simulation tools effectively. In this paper, a set of new tools are developed and integrated with part design software to provide automated support for analyzing process variability. Three levels of process simulations are developed, automated and integrated with optimization algorithms to generate robust processing feedback to the designer. With these tools interfaced with CAD design software, the designer is provided with both accurate manufacturability analysis and suggested geometry modifications for the part.

Introduction

In Liquid Composite Molding (LCM) processes, dry fiber reinforcement is placed within a mold cavity, which is then infused with catalyzed liquid resin until it is completely saturated. Once the resin cures the part is de-molded. Two most common variations of LCM processes are Resin Transfer Molding (RTM) and Vacuum Assisted Resin Transfer Molding (VARTM). RTM uses a rigid mold so that highly pressurized resin can be injected, whereas VARTM uses one-sided mold and a vacuum bag to seal the mold, and atmospheric pressure is used as the driving force. There are other techniques such as RTM-Light which uses a compliant mold. LCM is widely used because it allows one to manufacture complex net-shaped parts with good structural properties and surface finish. Mold filling simulation describes flow of resin through fiber preforms which are modeled as porous continuum. Many numerical simulations have been developed to forecast the mold filling patterns, which can predict the flow patterns once the geometric and local permeability information is provided as input. For perfectly deterministic, repeatable process in which the permeability may vary from location to location but will not change from one part to the next, only one simulation is necessary to identify the vent locations for desired inlet location(s) to fill the mold without any dry regions or voids. We have also developed a three dimensional Finite Element/Control Volume (FE/CV) based simulation called “Liquid Injection Molding Simulation” (LIMS) which can predict the flow patterns once the geometric and local permeability information is provided as input. For perfectly deterministic, repeatable process in which the permeability may vary from location to location but will not change from one part to the next, only one simulation is necessary to identify the vent locations for desired inlet location(s) to fill the mold without any dry regions or voids. These mold filling simulation tools can provide the user an estimation of the manufacturing design of the part. However, the functional design of a composite part is usually addressed separately and well in advance of the design of the manufacturing process, keeping with the tradition of first ensuring functional design.
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