

EFFECT OF COMPOSITION VARIATION ON ISOTHERMAL RAPID CURING RESINS FOR AEROSPACE APPLICATIONS

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ABSTRACT

To meet the projected demand for single-aisle composite aircraft in 2040, the production rate of these aircraft will need to increase by four to six times what is currently achievable. A composite manufacturing process with the potential to enable the targeted rates is isothermal resin infusion where infusion and cure occur at the same temperature. However, presently there is not an accepted aerospace-grade resin that can support this isothermal infusion process and maintain acceptable resin properties. Therefore, resin development initiatives have designed anionic catalyzed epoxy systems capable of isothermal infusion and rapid cure at a temperature below 100 °C in one hour. High-performance aerospace properties are achieved after undergoing a freestanding post-cure. The resins facilitate faster, energy efficient production cycles by reducing the time and temperature required for cure and eliminating temperature ramps typically required of materials used in the aerospace industry. This work discusses several of the developed resin systems and the impact of varying composition on rheological, thermal, and mechanical properties. Carbon fiber composites were fabricated for one composition by resin transfer molding to demonstrate the potential of these isothermal, rapid cure systems for meeting industry needs.

Keywords: resin transfer molding, isothermal cure, resin

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1. INTRODUCTION

1.1 Background

To meet the 2040 projected demand for single-aisle, composite aircraft, the aerospace industry requires the production of 80 to 100 aircraft per month, or a four to six time increase in manufacturing rates that are currently achievable [1]. A technology that could enable these rates is resin infusion as this technique minimizes part assembly time compared to conventional prepreg technologies and facilitates out-of-autoclave processing. The aerospace industry often fabricates composite parts using prepreg materials cured in autoclaves because this method reliably produces high-quality parts that meet industry standards. However, resin transfer molding (RTM), which is a form of resin infusion, has the potential to reproducibly achieve high-quality parts at a faster rate. The RTM process uses a closed rigid mold loaded with a dry fiber preform. Resin is injected into the mold and infused into the preform then cured to generate a composite part [2-5].

Current state-of-the-art aerospace-grade infusion resins require an infusion temperature below the cure temperature of the resin to prevent premature cure and viscosity increase. Following infusion,

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a temperature ramp is then necessary to bring the system to the resin cure temperature where it is then held for several hours to reach sufficient conversion. A final temperature ramp is then applied to reduce the temperature so that the part can be demolded without incurring deformation [2,6-8]. Therefore, the overall processing cycle time is defined by the following variables: the time to load the preform, the injection speed/resin flow rate, the time to complete any necessary temperature ramps, and the resin cure time. As such, there is opportunity for the cycle time to be significantly reduced by using an isothermal rapid curing resin system (Figure 1).

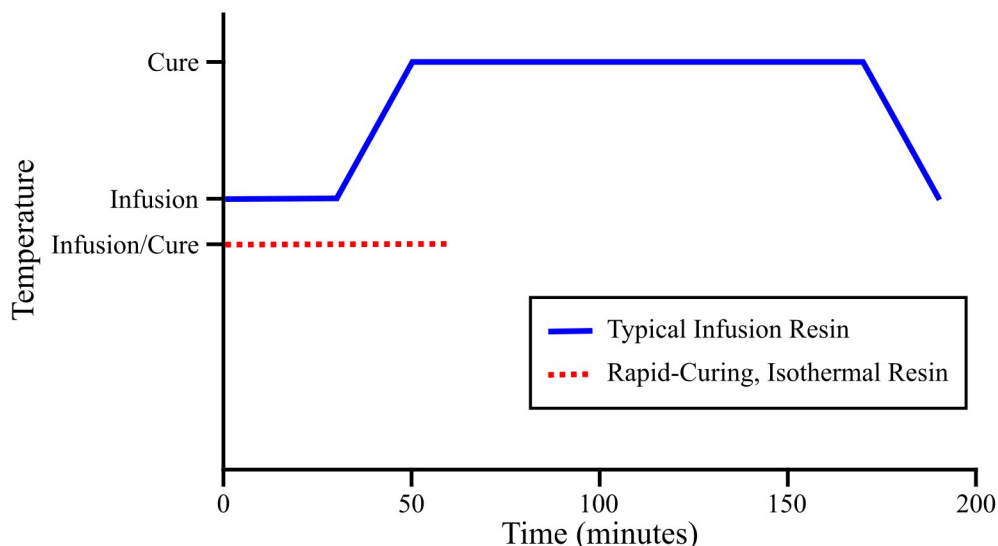


Figure 1. Representative processing cycles for a conventional resin infusion system and an isothermal rapid curing resin.

1.2 Isothermal Rapid Curing Resins

An isothermal rapid curing resin is infused, cured, and demolded at the same temperature. This increases processing efficiency by eliminating the temperature ramps typically required for infusion resins and optimizes cure kinetics to minimize the cure time required for the part to be demolded hot without deformation. However, the indicated resin needs to meet the requirements of high-performance aerospace-grade materials while being processable isothermally. Currently, there is no commercially available aerospace-grade resin capable of rapid isothermal infusion.

An approach that has captured attention, and the one leveraged in this work, is the use of imidazole catalysts to accelerate the conventional epoxy-amine addition polymerization mechanism commonly used in the aerospace industry. These catalysts facilitate expedited epoxy cure cycles that can be achieved at low temperatures ($<100\text{ }^{\circ}\text{C}$) [9-14]. Additionally, epoxies and amines are prevalent, commercially available materials with a wide variety of structures and functionalities, providing these systems with highly tunable resin properties and processing parameters via resin composition manipulation [15]. This has been taken advantage of to achieve targeted high-performance properties of aerospace-grade composites by leveraging aromatic, high functionality starting materials to create structural rigidity and a high crosslink density.

For the purposes of this work, a rapid processing cycle is defined as a total infusion/cure time of one hour with an infusion window of approximately 30 minutes. Furthermore, the infusion window

is defined as the amount of time the resin maintains a complex viscosity below 1000 cps at the isothermal temperature as measured by rheology. These processing parameters are met via the implementation of 2-ethyl-4-methylimidazole as a catalyst in tailored aromatic epoxy-amine systems. It has been shown that these systems attain high-performance aerospace-grade mechanical properties while exhibiting enhanced processing rates at temperatures below 100 °C [16]. This document details the impact of varying the catalyst concentration as well as the epoxy and hardener composition on processing temperature and mechanical properties. Finally, data is presented detailing the results of a carbon-fiber reinforced composite panel successfully fabricated using an isothermal rapid curing resin infused via the RTM process.

2. EXPERIMENTATION

2.1 Materials

N,N-Diglycidyl-4-glycidyloxyaniline (DGOA, Millipore Sigma, Fisher Scientific and Huntsman Corporation), 4,4'-methylenebis(N,N-diglycidylaniline) (TGMDA, Millipore Sigma and Fisher Scientific), 3-ethyl-3-oxetanemethanol (EOM, TCI America), neopentyl glycol diglycidyl ether (NPGDGE, TCI America), 3,4-epoxycyclohexylmethyl-3,4-epoxycyclohexanecarboxylate (CE, Millipore Sigma), m-phenylenediamine (mPDA, Millipore Sigma), 4,4'-diaminodiphenylsulfone (4,4'-DDS, Millipore Sigma and TCI America), Ethacure[®] 420 (E-420, Albemarle Corporation), 3,4'-oxydianiline (3,4'-ODA, Mitsui Petrochemical Industries, Ltd.), N-phenyl-p-phenylenediamine (Sigma Aldrich), 3-amino-1-propanol (3-APPO, TCI America), and Hexcel HexFlow[®] 1078 were used as received. 2-ethyl-4-methylimidazole (2Et4MeIm, Sigma Aldrich) was melted at 100 °C and remained a liquid after cooling to room temperature (RT). The dry carbon fiber (CF) used in composite fabrication was Saertex[®] 586 gsm, non-crimp, quasi-isotropic with a symmetric layup.

2.2 Resin Preparation

The designated amine and catalyst quantities were added to a tared heat-resistant glass vessel and the mixture was melted by heating in an oil bath maintained at 200 °C to 210 °C. After melting, the amine mixture was cooled to RT and the appropriate epoxy components added to the vial. The mixture was stirred using a metal spatula for 5 to 7 minutes until a homogeneous resin was obtained. Approximately 3 mL of resin was set aside for rheology and the remaining resin degassed in a vacuum oven at 50 °C. The degassed material was used to prepare samples for dynamic mechanical analysis (DMA).

2.3 Rheology

Rheological measurements were obtained on a TA Instruments ARES melt rheometer. All experiments were run using a frequency of 12.5 rad/s, a time per measurement of 5 s, and 5 % strain. A ramp rate of 5 °C/min was used to reach the isothermal temperature which was then held for the remainder of the experiment. Approximately 0.7 mL of resin was used to achieve a gap of approximately 1 mm between a 25 mm upper plate and 40 mm lower plate. Isothermal experiments were performed at three temperatures: 80 °C, 85 °C, and 90 °C, unless otherwise noted (Figure 2a). The cure time and gel point were determined for each isothermal experiment using equations 1 and 2:

Infusion Window

[1]

$$= (\text{Time for Complex Viscosity to reach } 1000 \text{ cps}) \\ - (\text{Time to Isothermal Temperature})$$

$$\text{Gel Point} = (\text{Time to Storage Modulus} > 1)$$

[2]

$$- (\text{Time to Isothermal Temperature})$$

The infusion window and gel point were plotted against each corresponding isothermal temperature, and a linear fit generated using the least-squares method (Figure 2b). The reported cure temperature was determined based on the 30-minute infusion window requirement. To do so, the equation for the best-fit line was solved for the temperature that resulted in a 30-minute infusion window.

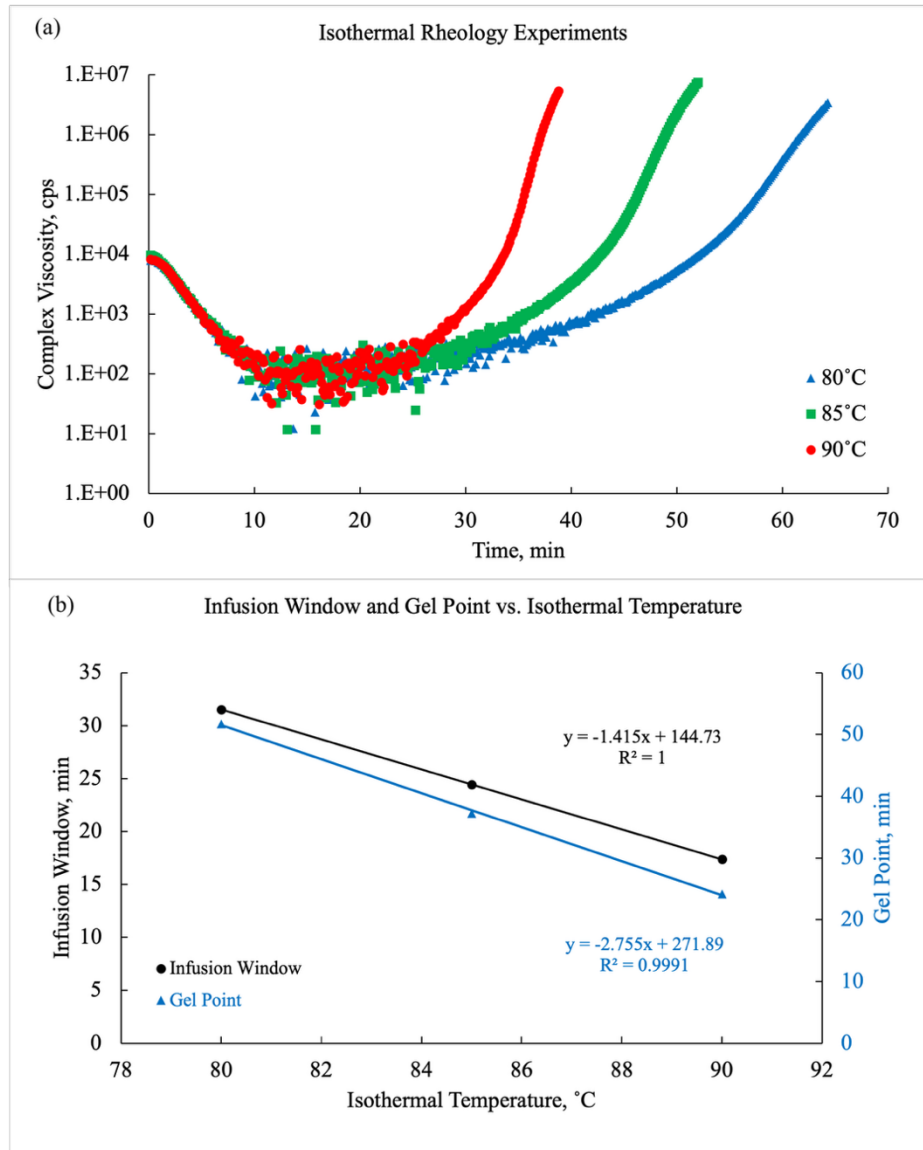


Figure 2. (a) Complex viscosity versus time rheological measurements for three isothermal experiments at 80 °C, 85 °C, and 90 °C. (b) Linear fit of infusion window and gel point versus isothermal temperature plot used to calculate the processing temperature.

2.4 Dynamic Mechanical Analysis

DMA samples that were 1 mm x 3 mm x 15 to 20 mm were prepared using approximately 0.5 mL of degassed resin. To do so, a mold made from glass microscopy slides coated with Loctite® Frekote in a configuration seen in Figure 3 was used.

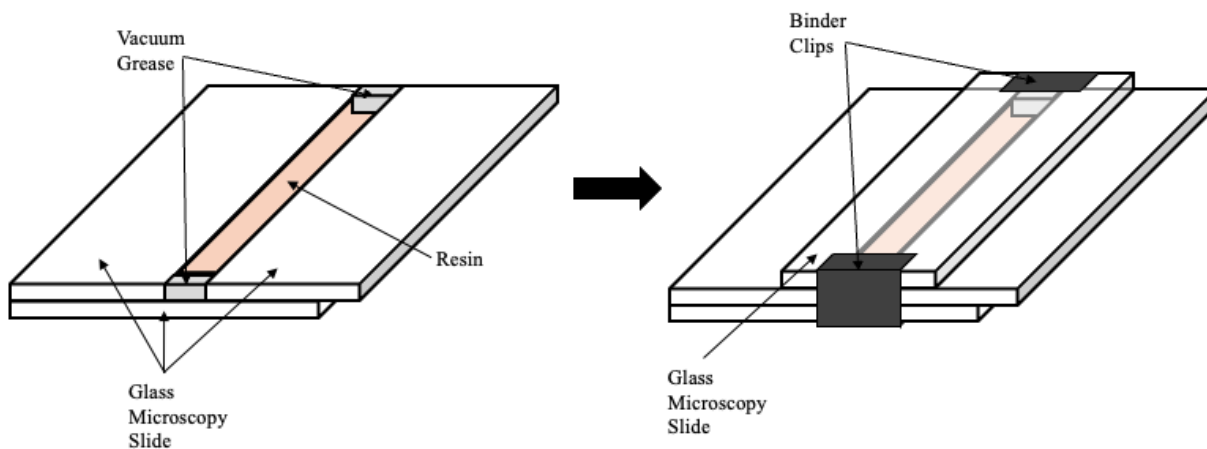


Figure 3. Process for generating samples for DMA.

The samples were cured for one hour in an oven at the appropriate isothermal temperature calculated from the rheological results. The samples were then removed from the molds at RT and placed in a glass recrystallization dish coated with aluminum foil and post-cured according to the following cycle:

- 100 °C, 30 min
- 120 °C, 30 min
- 140 °C, 30 min
- 165 °C, 30 min
- 195 °C, 30 min

(All temperature ramps were between 2 to 3 °C/min)

TA Instruments DMA Q800 and Q850 were used to obtain thermomechanical data. A preload force of 0.01 N, frequency of 1.0 Hz, and temperature ramp of 1 °C/min from -150 °C to 300 °C were used for all experiments.

The glass transition temperature (T_g) was identified as the onset of the highest temperature drop in storage modulus (E' T_g) and the highest temperature peak in the loss modulus (E'' T_g) and $\tan \delta$ ($\tan \delta$ T_g) curves. The storage modulus at room temperature (E' at RT) was taken at 25 °C.

2.5 Composite Fabrication

Composite parts were fabricated using Saertex® 586 gsm, non-crimp, quasi-isotropic dry CF fabric with a symmetric layup. The composite part thickness and layup were based on the requirements for tensile (ASTM-D3039, four plies), compression (ASTM-D6641, eight plies), and fracture toughness (ASTM-D7905, eight plies) test specimens [17-19]. A 150 mm x 50 mm x 0.075 mm

polytetrafluoroethylene (PTFE) film was placed on one edge as the crack starter for fracture toughness specimens.

Standard RTM practices employing a converging flow path were used to fabricate 150 mm x 150 mm composite panels with a target fiber volume fraction of 58.5 % as detailed in [20]. Panels were removed from the hot mold upon fabrication completion. The fabricated composite panels were then simply supported between two steel bars during the post-cure process and either a 3.3 kg or 0.8 kg weight was placed on the center of the panel for the eight ply or four ply lay-up, respectively. After the initial isothermal cure cycle, composite parts underwent a free-standing post-cure; this process was intended to determine whether deformation would occur during the post-cure process due resin softening.

3. RESULTS

The core components of the developed isothermal rapid curing resin formulations consisted of TGMDA, DGOA, mPDA, and 4,4'-DDS (Figure 4). These components were selected due to their prolific use in aerospace-grade epoxy resins owing to their stable aromatic structures and high level of functionality. For all compositions investigated herein, a hardener to epoxy equivalence ratio of 0.8 was used so that an excess of epoxy was present to reduce the occurrence of oxidation commonly experienced in amine-based hardener systems [21-22]. Detailed resin compositions are not described herein due to the status of a pending patent application pertaining to the resin chemistry. Readers interested in further information on investigated compositions can refer to [16].

The E' , T_g and E' at RT of the developed resin compositions were compared to those of HexFlow[®] 1078 (172 °C and 3.025 GPa, respectively), an infusion resin commonly used in the aerospace industry.

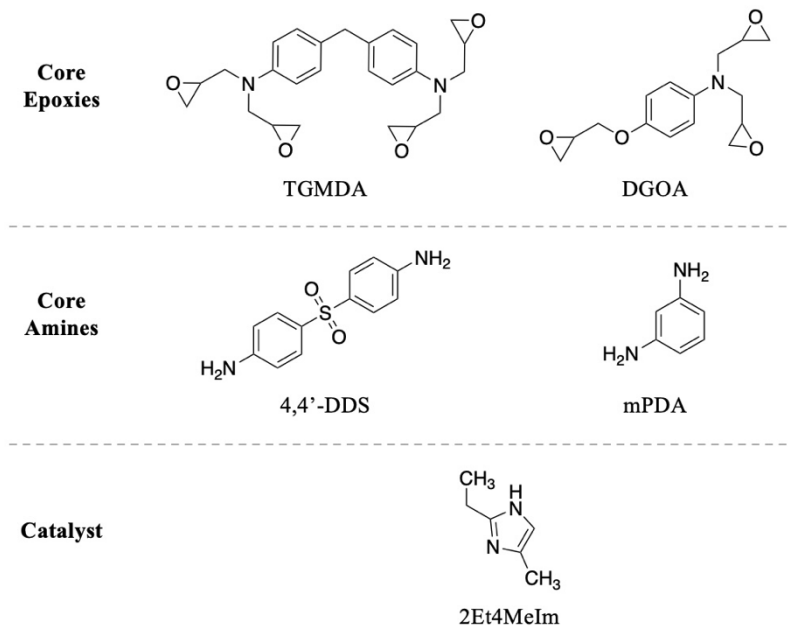


Figure 4. Molecular structures of the core components of the isothermal rapid curing infusion resin including TGMDA, DGOA, 4,4'-DDS, mPDA, and 2Et4MeIm.

3.1 Impact of Catalyst Concentration

Table 1. Resin compositions evaluated to determine the effects of catalyst concentration.

Resin ID	2Et4MeIm, wt %
1	0.00
2	0.65
3	0.90

The effect of catalyst concentration was first investigated to identify its influence on isothermal processing characteristics and neat resin mechanical properties. For this study, catalyst concentration was varied from 0 to 0.90 wt % (Table 1). Isothermal rheological data is presented in Table 2 detailing the impact of 2Et4MeIm loading on the infusion window and gel point at temperatures from 80 °C to 90 °C. Reaction rate was enhanced with increased catalyst loading as is evident by the decrease in infusion window and gel point times. Figure 5 demonstrates the correlation between the calculated isothermal cure temperature calculated from the rheological results and catalyst loading.

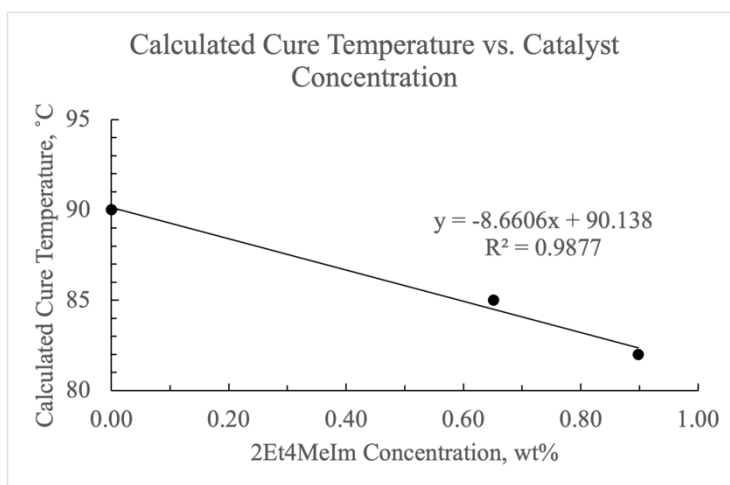


Figure 5. Plot of the calculated cure temperature versus catalyst concentration showing the linear dependence of processing temperature on 2Et4MeIm loading.

However, this data would suggest that an uncatalyzed core resin system could be processed isothermally at a low temperature to produce a structurally stable part in one hour. While the system does surpass the gel point at an isothermal cure temperature of 90 °C in that time, it has not reached a conversion high enough that it has structural rigidity when hot and therefore, does not meet the criteria outlined above. Resin 2 and 3, along with the resin systems discussed below, do exhibit sufficient cure within the one hour time constraint to be structurally stable when evaluated hot after the one hour isothermal cure cycle.

Table 2. Table of isothermal rheology experiments showing the impact of catalyst concentration on processing characteristics.

Resin ID	Infusion Window, min			Gel Point, min			Calculated Processing Temperature, °C
	80°C	85°C	90°C	80°C	85°C	90°C	
1	51.3	39.9	30.6	93.8	68.8	51.4	90
2	37.9	29.1	21.5	61.7	43.6	30.8	85
3	33.1	24.4	17.7	51.2	35.6	24.9	82

Table 3. Impact of catalyst loading on thermomechanical properties as measured by DMA.

Resin ID	E' at 25°C, GPa	T _g , °C		
		E' Onset	E'' Peak	Tan δ Peak
1	4.083	242	249	258
2	3.978	188	197	212
3	3.829	170	176	192

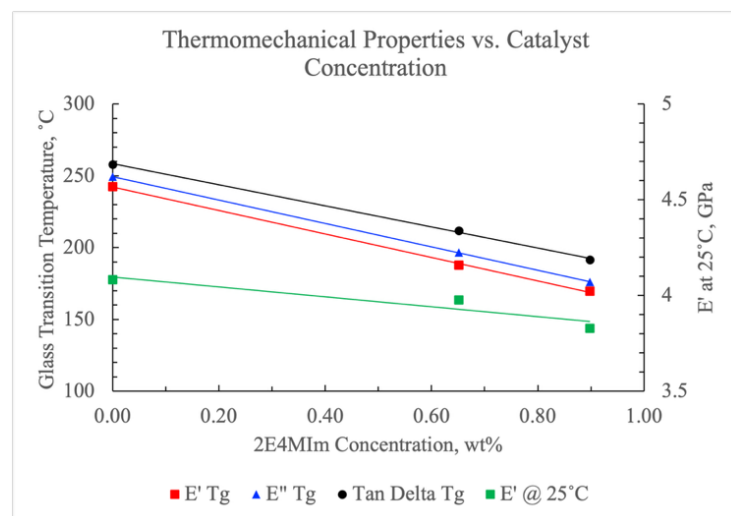


Figure 6. Effect of catalyst loading on T_g and E' at RT measured by DMA.

concentration of 1.0 wt % as seen in Table 4. These additives included EOM, NPGDGE, and CE (Figure 7), which are commonly used as reactive diluents in epoxy systems [23]. EOM is an oxirane, which is reactive with epoxy systems and contains an alcohol moiety. Alcohol groups have been shown to have a catalytic effect on epoxy-based systems by coordinating with an epoxy group and generating a lower energy transition state [24-25]. NPGDGE and CE are aliphatic epoxies that should also enhance reaction rate compared to the aromatic starting materials due to the lack of resonance stability. When reacting with a hardener molecule, epoxies form a charged transition state that can be stabilized by resonance in conjugated systems, e.g., aromatic structures.

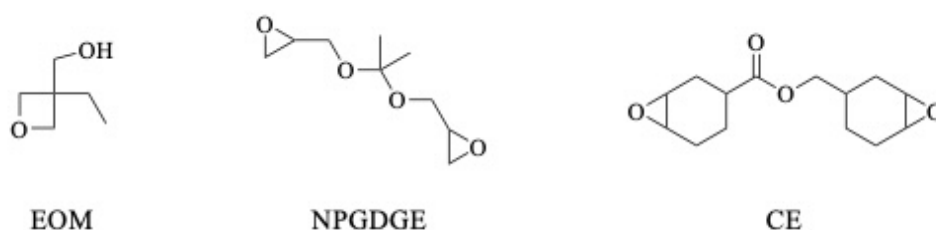


Figure 7. Molecular structures of epoxy additives EOM, NPGDGE, and CE.

Furthermore, the increase in catalyst loading also resulted in a reduction in thermomechanical properties. The T_g and E' at RT decreased linearly with increasing 2Et4MeIm loading (Table 3 and Figure 6). The E' T_g and E' at RT decreased by 30 % and 6 %, respectively, from Resin 1 to Resin 3.

3.2 Impact of Epoxy Additives

Several epoxies were selected to determine their effect on resin processing characteristics as compared to a baseline resin, Resin 4. Low concentrations of each additive (≤ 5 wt %) were added to the same core resin composition and 2Et4MeIm

However, aliphatic structures are not conjugated and therefore cannot stabilize the charge via resonance resulting in a less stable transition state and enhanced reaction rates.

Table 4. Compositions of Resins 4-7 formulated to evaluate the impact of EOM, NPGDGE, and CE on processing characteristics and thermomechanical properties.

Resin ID	Resin Additive
4	None
5	NPGDGE
6	CE
7	EOM

These behaviors are evident in the rheological data presented in Table 5. The epoxy system without reactive diluents has a calculated processing temperature of 83 °C whereas the addition of NPGDGE, CE, and EOM resulted in processing temperatures of 79 °C, 79 °C, and 71 °C, respectively.

Table 5. Table of isothermal rheology experiments showing the effects of EOM, NPGDGE, and CE on processing characteristics.

Resin ID	Infusion Window, min				Gel Point, min				Calculated Processing Temperature, °C
	75 °C	80 °C	85 °C	90 °C	75 °C	80 °C	85 °C	90 °C	
4	-	31.5	24.5	17.4	-	51.7	37.2	24.2	83
5	-	29.4	20.8	36.3	-	54.5	36.6	77.2	79
6	37.0	28.9	21.2	-	78.9	55.2	37.4	-	79
7	26.2	21.8	17.1	-	61.5	44.2	30.3	-	71

Furthermore, these materials had an impact on the thermomechanical properties of the core isothermal Resin 4 (Table 6). EOM (Resin 7) had a negative impact on T_g , reducing $E' T_g$ by 47 °C as compared to Resin 4. However, it resulted in a slight increase in E' at RT of 0.308 GPa. NPGDGE and CE had a beneficial effect on thermomechanical properties. The addition of NPGDGE (Resin 5) increased the E' at RT of Resin 4 by 0.185 GPa, while the addition of CE (Resin 6) increased $E' T_g$ and E' at RT by 17 °C and 0.102 GPa, respectively.

Table 6. Effects of the addition of EOM, NPGDGE, and CE to Resin 4 on thermomechanical properties as measured by DMA.

Resin ID	E' at 25°C, GPa	T_g , °C		
		E' Onset	E'' Peak	Tan δ Peak
4	3.795	165	188	200
5	3.897	182	188	204
6	3.980	167	172	189
7	4.103	118	120	144

3.3 Impact of Hardener Additives

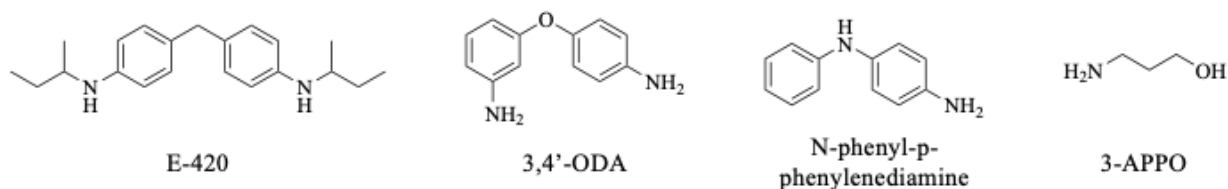


Figure 8. Molecular structures of hardener additives E-420, 3,4'-ODA, N-phenyl-p-phenylenediamine, and 3-APPO.

Table 7. Compositions of Resins 8-12 formulated to evaluate the effects of E-420, 3,4'-ODA, N-phenyl-p-phenylenediamine, and 3-APPO on processing characteristics and thermomechanical properties.

Resin ID	Resin Additive
8	None
9	E-420
10	3,4'-ODA
11	N-Phenyl-p-Phenylenediamine
12	3-APPO

A set of amine modifiers seen in Figure 8 were also evaluated and compared against a baseline resin composition comprised of the core resin components, Resin 8 (Table 7). The comparative baseline resin for this investigation deviated from Resin 4 used above. Baseline resin compositions were developed in an iterative fashion to optimize material properties and processing characteristics for isothermal resin infusion. Resin 8 displayed improved thermomechanical properties compared to Resin 4 and was therefore used for this study. The stoichiometric ratios of the core resin components were kept constant in Resins 8-12 and low concentrations of the amine modifiers (≤ 5 wt %) were introduced. Akin to the epoxy additives evaluated above, the variation in impacts of these materials were due to the differences in their molecular structures [23]. E-420 and N-phenyl-p-phenylenediamine are variations of secondary diamines that may afford steric hinderance during reaction. The structure of the diamine 3,4'-ODA is non-linear, and 3-APPO is an aliphatic primary amine containing a reactive alcohol group.

Table 8. Isothermal rheology data for Resins 8-12 showing the effects of E-420, 3,4'-ODA, N-phenyl-p-phenylenediamine, and 3-APPO on processing characteristics.

Resin ID	Infusion Window, min			Gel Point, min			Calculated Processing Temperature, °C
	80°C	85°C	90°C	80°C	85°C	90°C	
8	32.1	24.6	17.8	53.0	36.5	25.2	82
9	38.3	29.5	20.8	58.2	40.7	28.3	85
10	31.5	23.8	17.1	51.4	35.5	24.5	82
11	33.4	24.1	17.1	51.5	35.3	24.4	82
12	34.0	24.7	18.2	53.5	37.4	25.8	82

The calculated cure temperatures based on isothermal rheology experiments for each of the prepared resin compositions are presented in Table 8. The addition of E-420 reduced the reaction rate of the system compared to Resin 8, resulting in an increase in calculated cure temperature from 82 °C to 85 °C. The addition of 3,4'-ODA, N-phenyl-p-phenylenediamine, and 3-APPO did not have a significant effect on the processing parameters of core Resin 8 and maintained the calculated isothermal processing temperature of 82 °C.

Table 9. DMA data from Resins 8-12 showing the impact of the addition of E-420, 3,4'-ODA, N-phenyl-p-phenylenediamine, and 3-APPO on thermomechanical properties.

Resin ID	E' at 25°C, GPa	T _g , °C		
		E' Onset	E'' Peak	Tan δ Peak
8	3.741	195	210	234
9	3.708	136	146	163
10	3.504	161	170	181
11	3.637	158	166	176
12	3.761	152	162	173

Additionally, all amine-based modifications to the baseline Resin 8 resulted in diminishing thermomechanical properties, as can be seen in Table 9. The E' T_g and E' at 25 °C of Resin 8 was 195 °C and 3.741 GPa, respectively. However, the E' T_g for Resins 10 through 12 were 35 °C to 40 °C lower than Resin 8 with E-420 (Resin 9) exhibiting the largest decrease. The E' at RT were comparable to the baseline Resin 8 with the exception of Resin 10 (3,4'-ODA) and Resin 11 (N-phenyl-p-phenylenediamine) which caused a 6 % and 3 % decrease, respectively.

As noted, the impact on the thermomechanical properties of Resin 8 was due to the molecular structure of the amine additives. E-420 and N-phenyl-p-phenylenediamine possess secondary amines. The incorporation of these materials results in a network structure with a greater proportion of linear, thermoplastic-type character resulting in a reduction of the overall crosslink density and lower thermomechanical properties. The molecular structure of 3,4'-ODA contains meta and ether linkages which enhance the free volume and flexibility of the network structure causing a decrease in mechanical properties. Finally, 3-APPO has an aliphatic structure which increases the flexibility of the generated thermoset network thereby reducing the structural properties.

3.4 Composite Fabrication

Resin 4 was selected for infusion of a CF reinforced panel to evaluate the processing characteristics of an isothermal rapid curing resin by RTM. Composite panels (150 mm x 150 mm) were successfully fabricated as can be seen in Figure 9.

The mechanical performance of the panels was evaluated via tensile, compression, and fracture toughness properties and compared to a resin commonly used in the aerospace industry, 1078, that was processed following the procedures outlined in the datasheet [8] using same RTM method and CF reinforcement.

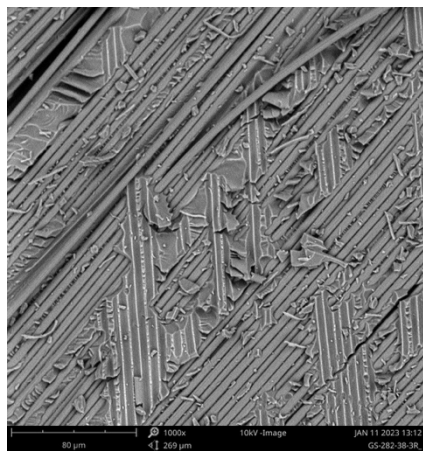


Figure 6. SEM image of a composite fracture surface after ENF testing showing poor fiber-matrix interaction.

The tensile strength, tensile modulus, and compressive strength of composites fabricated using isothermal rapid curing Resin 4 were 90 %, 98 %, and 113 % of 1078, respectively. However, the G_{IIC} was 62 % of 1078. Possible factors that could contribute to the low fracture toughness value include unoptimized resin-fiber interfacial interaction and/or low resin toughness [26, 27]. The SEM image in Figure 10 displays an example of the poor fiber-matrix interfacial interaction observed in these composite systems thus far evidenced by the smooth surfaces where fiber pulled away from the resin during testing. Work is currently ongoing to optimize these parameters and increase the composite fracture toughness.

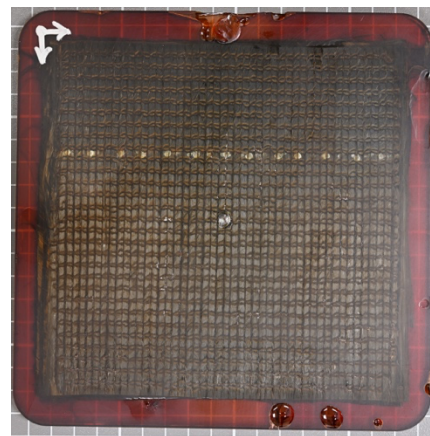


Figure 9. A successful carbon-fiber reinforced composite panel fabricated via RTM from isothermal rapid curing Resin 4.

4. CONCLUSIONS

It was shown that isothermal rapid curing resins leveraging catalyzed epoxy-amine chemistry and processed via RTM show significant promise in achieving the composite properties required of systems used in the aerospace industry. A core epoxy-amine system comprised of TGMDA, DGOA, mPDA, 4,4'-DDS, and 2Et4MeIm was developed. These resin formulations could be infused and cured isothermally in one hour at a temperature below 100 °C to produce a part of structural rigidity when removed from a hot mold and capable of undergoing a simply supported post-cure cycle without deformation.

Modifications to the core catalyzed epoxy-amine system were explored for their impacts on processing characteristics and thermomechanical properties. Increasing the catalyst loading for a given resin composition resulted in a decrease in the calculated isothermal processing temperature. However, this was also accompanied by a reduction in T_g and storage modulus.

The impact of introducing low levels of aliphatic epoxies of various molecular structures to the base resin was explored. In all cases, the calculated isothermal processing temperature was reduced

with these aliphatic additives, but there were varying effects on the thermomechanical properties. The addition of NPGDGE enhanced the T_g while EOM and CE had a detrimental effect.

Similarly, low levels of amine additives were studied for their impact on processing characteristics and material properties. The only additive to have impact on the calculated processing temperature was E-420 that may be associated to the hinderance provided by the sec-butyl group of the secondary amine. However, each of these additives had an antagonistic effect on the thermomechanical properties of the core resin system due to the secondary amine characteristics of E-420 and N-phenyl-p-phenylenediamine, the meta and ether linkages present in 3,4'-ODA and aliphatic structure of 3-APPO.

The response of the core resin system to each of the introduced modifications shows its properties can be tuned via resin composition modification. With the knowledge gained regarding how specific molecular structures impact the processing characteristics and thermomechanical properties of the core system, a formulation can be tailored to optimize parameters such as isothermal processing temperature, infusion window, T_g , E' , and fracture toughness. This is valuable for designing a resin system for targeted applications such as composite materials with enhanced processing efficiency for the aerospace industry.

An exemplary resin was selected for composite fabrication via isothermal RTM, and a CF reinforced panel was successfully generated. The mechanical properties of the composite were measured and compared to those of an infusion resin currently used in the aerospace industry, 1078. While the evaluated structural properties, including tensile strength, tensile modulus, and compression strength, showed comparable values to the composite fabricated with 1078, the fracture toughness requires improvement. Additionally, it should be noted that further structural characterization is required to fully assess the capability of this resin to be integrated into the aerospace industry.

5. ACKNOWLEDGMENTS

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The use of trade names of manufacturers does not constitute an official endorsement of such products or manufacturers, either expressed or implied, by the National Aeronautics and Space Administration.

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