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FABRICATION OF FIBER/METAL HYBRID COMPOSITES BY THE VARTM PROCESS

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SUMMARY: Metallic coated fabrics are produced by plasma spray coating of metal powders onto the surface(s) of biaxial, woven fiber fabrics. Multiply layers of the metallic coated fiber fabrics are stacked together to produce a preform, which can be infused by liquid molding techniques. An experimental program was performed to determine the compaction characteristics of S2-glass fiber, 8HS woven fabric, plasma spray coated with aluminum alloy powder. The results showed that the compaction response of the metallic coated fabric is significantly different than that of the compaction behavior of the S2-glass fiber, 8HS woven fabric, and depends on the amount of metal deposited on the fabric surface(s). Further investigations need to be performed to better understand the compaction mechanisms and the relationship between metal deposition amounts and the compaction characteristics.

KEYWORDS: Fiber Metal Laminates, Hybrid Laminates, Metal Coated Fabrics, Plasma Spray Coating, Compaction Characteristics, VARTM

INTRODUCTION

Metal/composite hybrid laminates such as ARALL™ and GLARE™ are fabricated by stacking alternate layers of metallic sheets and fiber-reinforced polymeric-matrix prepreg plies [1]. The hybrid lay up is then processed under elevated temperature and pressure to consolidate the laminate and cure the polymer resin which bonds the fiber layers to the metallic sheets. Metal/composite hybrid laminates have mechanical and environmental properties that are superior compared with monolithic metal alloys or fiber reinforced, polymer matrix composite laminates.

Metallic coated fabrics, produced by plasma spray coating of metal powders onto the surface(s) of biaxial, woven fiber fabrics, are being investigated as an alternative to hybrid laminates that are fabricated by stacking alternate layers of polymer matrix prepreg plies and metallic foil plies

[2]. A low pressure RF plasma coating process is used to heat and accelerate the metal powder particles [3,4]. The metal particles become molten and are deposited on the surface of the substrate fabric where they rapidly solidify and form a strong metal to fiber bond. The amount of metal deposited onto the fabric can be controlled such that the resulting metallic coated fabric is porous. Multiply layers of the metallic coated fiber fabrics are stacked together to produce a preform, which can be infused with a liquid polymer matrix resin using one of the low-cost liquid molding processes such as vacuum assisted resin transfer molding (VARTM). Hence, these new metallic coated fabrics could potentially reduce the manufacturing cost and improve the bond strength between the fibers and metal of hybrid laminates.

In order to fully understand the mechanisms observed in the VARTM process, computer models are currently being developed to predict the preform compaction and relaxation that occur during resin infiltration. This is critical to accurately predicting the preform fiber volume fraction (V_f) and the resin flow behavior due to the flexible vacuum bag and low compaction pressures. One key material input property required by VARTM flow simulation models is the preform compaction behavior. The compaction response and the preform permeabilities are coupled with the state of the preform, such as the fiber volume fraction and the saturation. In this investigation, an experimental program was performed to measure the compaction characteristics of glass-fiber, woven fabrics coated with aluminum alloy particles. The resulting data can be fit to empirical equations which can be used as material input parameters in process model simulations.

PREFORM CHARACTERIZATION

Materials

The glass/aluminum hybrid preforms were constructed by plasma spray coating an aluminum alloy powder onto the surface(s) of a S2-glass fiber, 8HS woven fabric. Shown in Fig. 1 is a photograph of the metal coated and fabric surfaces of the glass/aluminum hybrid preform.

Fig. 1 S2-glass fiber, 8HS woven fabric single side coated with an aluminum alloy at a deposition of 0.37 g/ in^2.

Three different spray configurations were tested. These include single side coated at an aluminum alloy deposition of 0.37 g/ in^2, single side coated at an aluminum alloy deposition of

0.72 g/in^2 and both sides coated at 0.36 g/in^2. Identification and specifications of the glass/aluminum hybrid preforms are shown in Table 1.

Table 1 Glass/aluminum hybrid preform specifications

ID	Material	Spray Configuration	Al deposition	Cloth density	Total Wt.
LPS-143	Monotape (Si + Al-Mg-Mn-Sc-Zr)	Single sided, 150 grams sprayed, THIN	0.37 g/in^2	0.19 g/in^2	0.56 g/in^2
LPS-146	Monotape (Si + Al-Mg-Mn-Sc-Zr)	Single sided, 300 grams sprayed, THICK	0.72 g/in^2	0.19 g/in^2	0.91 g/in^2
LPS-148	Monotape (Si + Al-Mg-Mn-Sc-Zr)	Side 1 of 2, 150 grams sprayed	0.36 g/in^2	0.19 g/in^2	0.55 g/in^2
	Monotape (Si + Al-Mg-Mn-Sc-Zr)	Side 2 of 2, 150 grams sprayed	0.36 g/in^2	already included	0.91 g/in^2
LPS-149	Monolithic (Al-Mg-Mn-Sc-Zr)	No Cloth, 150 grams sprayed	0.40 g/in^2	No Cloth	0.40 g/in^2

Compaction Measurements

The basic compaction characteristics of the hybrid materials were measured using the fixture shown in Fig.2. Preform specimens were carefully cut into 5.08 cm square samples and the thickness was measured at four locations. Four ply thick samples were placed into the cavity of the fixture. The fixture was mounted between the upper and lower platens of a MTS Insight 100 kN Material Testing Machine as shown in Fig. 2.

To determine the compaction behavior, a compressive load was applied at a 1.3 mm/min cross head rate until the desired compaction force is reached. At that point, the cross head is stopped and the preform is allowed to relax. When the relaxation has ceased as indicated by the load becoming steady, the compaction force and preform thickness were measured. Preform thickness was measured using a Mitutoyo Digimatic Indicator with a resolution of 0.001 mm. For the tests conducted, data were taken to compaction loads of 200 kN. Shown in Fig. 3 are the compaction characteristics of the LPS 143 glass /aluminum hybrid preform. The results show that there are significant differences in the compaction characteristics between different samples of the same hybrid preform. This may be due to the differences in the initial thickness of the preforms. Another possibility is the relaxation of the preform.

Fig. 2 Compaction test fixture.

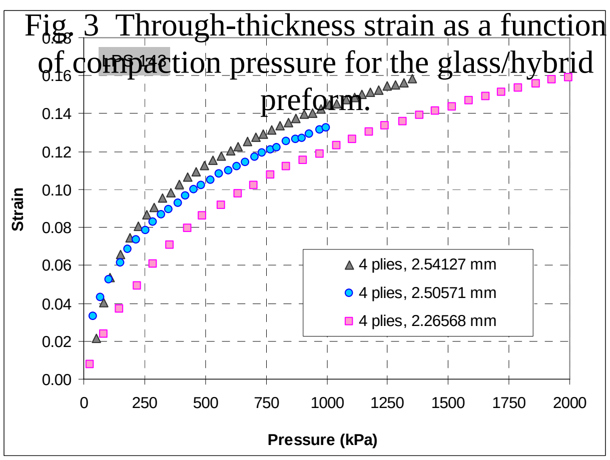

Fig. 3 Through-thickness strain as a function of compaction pressure for the glass/hybrid preform.

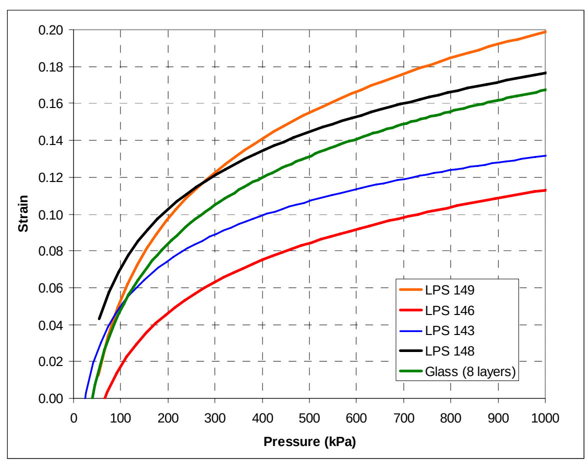

Fig. 4 A comparison of the compaction characteristics for the glass-aluminum hybrid preforms and glass fabric.

A comparison between the compaction characteristics of the glass/aluminum hybrid preforms and compaction characteristics of the glass fabric and pure aluminum alloy are shown in Fig. 4. Each curve represents a nonlinear least squares curve fit to the data sets for each of the glass/hybrid and glass fabric preforms. It is evident from the figure that the metal coating significantly influences the compaction behavior of the glass fabric. For the single side coated preforms, increasing the aluminum alloy deposition decreased the strain for a given compaction pressure. However, coating both sides of the fabric with the aluminum alloy results in a compaction strain that is higher that the glass fabric for a given compaction pressure. Note, that the pure aluminum alloy had the highest compaction strain.

CONCLUSIONS

The compaction characteristics of metallic coated woven fiber fabrics were measured. The fabrics were constructed by plasma spray coating aluminum alloy powder onto the surface(s) of a S2-glass fiber, 8HS woven fabric. The amount of metal deposited onto the fabric can be controlled such that the resulting metal coated fabric is porous. Test specimens cut from the same batch of material showed a fairly large variation in the compaction response. A possible reason for this may be the variation in the thickness of the metal coating on the fabric surface(s). Metal coated fabrics with different aluminum deposition amounts and spray configurations showed significantly different compaction responses compared with the compaction behavior of S2-glass fiber, 8HS woven fabric. Additional studies will need to be performed in order to understand the effects of metal deposition amount and spray configuration on compaction behavior. Once the compaction behavior of the metallic coated fiber fabrics is known, future studies will be performed to measure the permeabilities of the material. The compaction and permeability data are necessary inputs into a simulation model to determine the feasibility of fabrication of fiber/metal hybrid composites by VARTM.

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