

Influence of Automated Fiber Placement (AFP) Parameters over Permeability and Performance for Dry CF Laminates [†]

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Abstract: AFP process has the advantage of producing high-performance components and reducing the manufacturing time and defects introduced in the final material thanks to the highly automated process, compared with more traditional methods. Selecting inappropriate AFP process parameters can influence the permeability of the preforms being manufactured and the later mechanical performance of the final component. This paper reviews in detail the influence of the main AFP process parameters (deposition velocity, compaction force and temperature) over the adhesion properties between carbon fiber tapes. Later, three parameter combinations are selected to evaluate their influence over preform permeability and the mechanical performance of the composite after the resin injection process (RTM).

Keywords: AFP; preforming; parametrization; RTM



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1. Introduction

The Automated Fiber Placement (AFP) technique is an innovative process widely used in the manufacturing of aerospace and automotive components, sectors where weight optimization and mechanical properties are critical factors. This method enables the transition from manual lamination processes (hand layup) to an automated fiber deposition approach for the fabrication of composite materials [1].

One of the most notable characteristics of this technique is its ability to achieve high fiber deposition rates, leading to greater production efficiency compared to traditional lamination methods [2]. The AFP process allows for the optimization of both fiber orientation and the amount of fiber needed, facilitating the fabrication of parts with complex geometries that would be challenging to produce using other methods. This not only enhances process efficiency but also improves the structural properties of the final component [3]. However, a critical aspect is the control of defects generated during fiber deposition (wrinkles, gaps, overlaps, etc.). These defects can negatively affect subsequent manufacturing processes, compromising the final quality of the manufactured part [4].

The combination of AFP with the Resin Transfer Molding (RTM) process leverages the advantages of both techniques, optimizing the production of advanced components. Dry fiber preforms are initially manufactured using AFP, enabling design flexibility for complex geometries and higher precision [5]. Subsequently, these preforms are infused with resin in a closed mold during the RTM process, ensuring uniform resin distribution and structural

integrity. This combination of technologies not only enhances production efficiency but facilitates the fabrication of components with higher mechanical properties.

AFP parameters are particularly critical, as they directly influence the final quality of the component produced through the RTM process. Thus, it is important to understand the effect of the AFP process parameters on the final preform quality (tape adhesion) and, at the end, on the composite mechanical performance. A summary of parameters is presented in Table 1.

Table 1. Summary of main AFP process parameters.

Heat Source	Reinforcement	Heat Power [W]	Temperature at Nit Point [C]	Compaction Force (AFP Head) [N]	Deposition Velocity [mm/s]		Ref.
					1st	Other	
Laser 3 kW	Carbon fiber + epoxy/thermoplastic binder	-	200	446	-	400	[6]
Laser	Carbon fiber 24K 194 g/m ² + thermoplastic binder	800	200 (at 800 m/s) 320 (400 m/s)	200	400	800	[7]
Laser 3 kW	Carbon fiber + binder	200 357	200 300	446	-	400	[8]
Hot Gas	N/S	-	176	311	25.4	101.6	[9]
Laser	PRISM TX1100	-	160	160	-	200	[5]
Laser 6 kW	Carbon fiber	-	-	446	-	100, 200, 400, 800	[10]
Laser	Carbon fiber 24K UD 194 g/m ² + thermoplastic binder	800	250	200	-	100	[4]
IR halogen lamp	Carbon fiber	360	110	-	-	850	[11]

Every material needs to be optimized with the adequate process parameters. Based on this overview, many of the deposition velocities used are quite low, possibly not taking advantage of the AFP process capacity to be used for mid–high volume manufacturing industries. Temperature depends on the material being processed (heating source or power needed). Compaction force and deposition velocity must be adjusted to maintain a specific temperature to bond and consolidate the layers of material being processed.

In this work, a combination of AFP process parameters were established for a specific reference of carbon fiber tapes. The adhesion properties between layers after a series of combinations of parameters were evaluated. Also, the influence of these parameters over the material performance was studied by performing permeability and compression tests of RTM panels. A correlation between AFP parameters and final composite properties is presented.

2. Materials and Methods

2.1. Materials

The reinforcement is a carbon fiber tape especially formulated for the AFP/ATL process (Teijin Toho Tenax IMS65 E23 24K 830tex). The tape reference is TeXtreme 5172 194 UD IMS65 VO/25:194, with an areal weight of 194 g/m² and a ply thickness of 0.182 mm. The tape width is 25.4 mm, and the tape integrates a thermoplastic binder (PA1206, 6 g/m²). The matrix is the Hexcel HexFlow RTM6-2.

2.2. Tests and Equipment

A COMBILITY AFP head was used to manufacture tapes and preforms. This head allows roll compaction forces of up to 500 N on the layering surface. Heating is achieved by an infrared laser system (VCSEL, 2.4 kW). The AFP head is mounted on a R-2000iC FANUC robot (Figure 1).

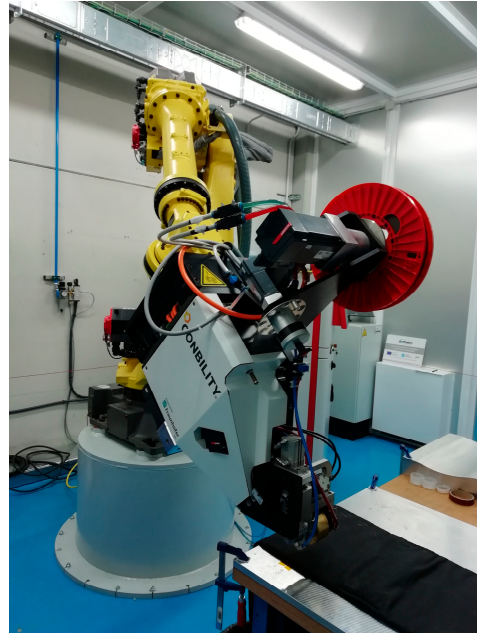
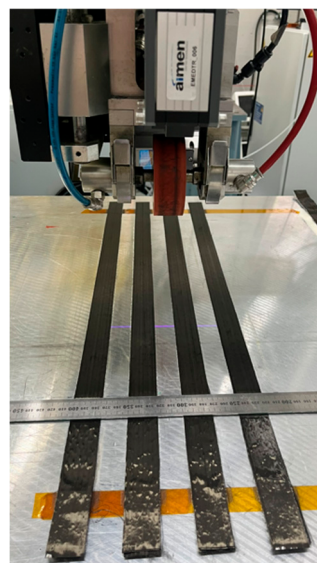


Figure 1. PrePro3D COMBILITY head on AIMEN facilities.

Adhesion between the dry fiber tapes was evaluated following a peeling test (M. de Rooij et al. [12] and F. Weidmann et al. [13]). This is not a standardized method, but it gives a quantitative assessment of the bonding properties between the CF tapes. CF coupons (dry fiber) of 135 ± 5 mm were manufactured by layering 4 layers. Before each trial, the weight and friction produced by the tooling were tared from the equipment. Tests were carried out in a 10 kN SHIMADZU AG-X Plus universal testing machine (Figure 2).



(a)



(b)

Figure 2. Peeling test performed on the dry CF tapes. (a) Peeling coupon manufacturing with the AFP head. (b) Peeling test tooling mounted on the testing machine.

Resin injection was carried out using an RTM machine (ISOJET Equipements, France). Unidirectional panels were manufactured on a steel mold (310 mm length, 160 mm width, 2 mm thickness). Coupons of 140×13 mm, 2 mm thick, were extracted to evaluate the compression properties (ASTM D6641 [14]), both parallel to the fiber direction (0° , 6 coupons) and perpendicular to it (90° , 6 coupons). The test velocity was fixed at 1.3 mm/s.

Permeability tests (ISO 4410:2023 [15]) were carried out using a steel tooling designed for this purpose, integrating a 15 mm thick PMMA transparent window. Silicon oil (SI0025005P) with a viscosity of 100 cP was used as test fluid. Thickness was fixed at 2 mm using a steel frame, and preform dimensions were 150 mm in width and 250 mm in length.

2.3. Manufacturing Procedure

2.3.1. AFP Peeling Samples

From all the parameters that affect the AFP process (Table 1), it was determined that there are three that have a direct influence over the final material performance: AFP head/roll compaction force, deposition velocity and the heating power that is applied over the material. Compaction force will affect final preform thickness, affecting its permeability, besides ensuring proper adhesion between layers when the binder is activated. Deposition velocity has a main impact over the productivity of the process, especially on large-scale components, affecting the amount of heat that the fibers receive at a determined heating power. Power has a direct impact over the temperature at the tape surface, changing the behavior of the binder that is integrated in the tapes.

A DoE was established to create a process window for this specific material, considering quality and productivity. The DoE was based on a Central Composite Design (CCD) methodology to define the combinations. Based on the SoA, the main limits were defined, taking values that contained all the possible scenarios. However, the feasibility of the variable limits had to be analyzed, since they may have no applicability with these materials. After performing some trials, it was determined that compaction forces under 250 N (50%) created tapes that slide and have no adhesion. Deposition velocity beyond 400 mm/s surpasses the head reliability and control, since for the tape length defined previously it is not possible to achieve a uniform deposition, and a power input greater than 400 W makes the tapes burn. With this, new variable limits for the DoE were established to be implemented (Table 2), and 4 repetitions were made for each case.

Table 2. Initial DoE established.

Group	Deposition Speed [mm/s]	Heat Power [W]	Compaction Force (AFP Head) [N]
1	100	100	250
2	400	100	250
3	100	400	250
4	400	400	250
5	100	100	500
6	100	100	500
7	100	400	500
8	400	400	500
15 *	250	250	375

* Central point added.

2.3.2. Permeability and RTM Samples

Some DoE groups were selected: the lowest, middle and higher peeling strengths, to analyze their permeability values and performance. Regarding permeability, every preform

has three different zones to calculate it; areas close to the edges are discarded to avoid possible race-tracking issues.

RTM preforms were injected first at low pressure (0.7 bars + full vacuum) to ensure proper impregnation through the fibers and to avoid porosity by trapped air. After completing the injection, a post-filling at 6 bars and resin bleeding strategies were applied to ensure full impregnation, constant fiber volumetric fraction and low void content. After curing, panels were demolded, and coupons were extracted by waterjet cutting.

3. Results

3.1. Peeling Test

Table 3 summarizes the behavior of the carbon fiber tapes evaluated by the peeling test. In some groups, it was not possible to measure the peeling strength due to inadequate binder activation, which led to having no adhesion between layers.

Table 3. DoE results for the evaluation of the peeling strength.

Group	Deposition Speed [mm/s]	Heat Power [W]	Compaction Force (AFP Head) [N]	Peeling Strength [N/m]
1	100	100	250	No adhesion *
2	400	100	250	No adhesion *
3	100	400	250	77.6 ± 13.5
4	400	400	250	29.7 ± 12.1
5	100	100	500	No adhesion *
6	100	100	500	No adhesion *
7	100	400	500	123.0 ± 14.7
8	400	400	500	71.2 ± 8.1
15	250	250	375	44.1 ± 2.2

* Values specified as “No adhesion” mean that there was no physical bonding between the layers, making performing the test impossible. Since the groups were defined during the DoE, these values were not adjusted or modified.

Higher peel strength is obtained in the groups where the heating power was higher, and the deposition velocity was the lowest (Table 3). These parameters affect directly the temperature that the tapes reach during the AFP process, influencing the quality of the binder in the fibers. In the case of low–no adhesion between layers, the temperature oscillated around 60 °C (Figure 3).

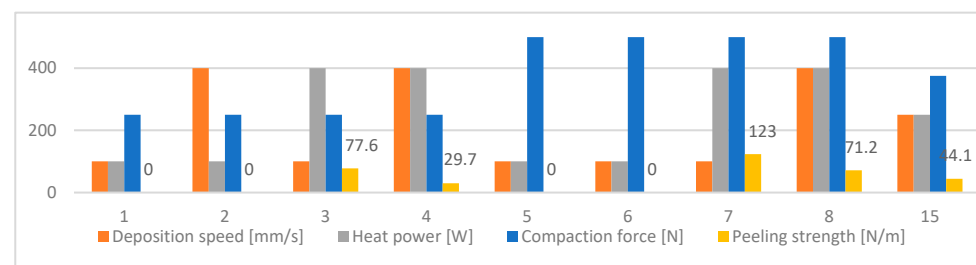


Figure 3. Effect of AFP parameters on tape adhesion (peeling test).

Based on these results, groups 3, 4 and 7 were selected to carry out the analysis on permeability and RTM injections.

3.2. Permeability Test

Even though the AFP path planning was created to have a net layer surface (zero gap) through the process itself, some local points of gaps/overlaps appear over the preforms,

making some preferent channels during the test; these specific zones were discarded. Table 4 summarizes the results.

Table 4. Preform permeability by applying the AFP parameters for the selected groups.

Group	Permeability [m ²]				Peeling Strength [N/m]
	K _{z1} (Zone 1)	K _{z2} (Zone 2)	K _{z3} (Zone 3)	Mean	
3	7.0354×10^{-12}	8.1455×10^{-12}	9.1325×10^{-12}	$8.1045 \pm 1.05 \times 10^{-12}$	77.6 ± 13.5
4	10.204×10^{-12}	9.8208×10^{-12}	26.6957×10^{-12}	$15.661 \pm 9.63 \times 10^{-12}$	29.7 ± 12.1
7	4.2073×10^{-12}	9.6302×10^{-12}	-	$6.9188 \pm 4.82 \times 10^{-12}$	123.0 ± 14.7

The permeability values show a correlation with the peel strength values (Figure 4). In the case of group 4, having the lowest peel strength, the highest permeability values are obtained. This is because lower strength indicates that the fiber tapes are less compacted compared to the other groups, resulting in increased permeability. In this group, the average permeability value is 15.5661×10^{-12} m². Group 7, which has the highest peel strength, shows the lowest permeability values, with an average of 6.9188×10^{-12} m². This inverse relationship is explained by the fact that the tapes are more cohesively bonded, reducing their permeability to fluid flow. Finally, group 3 presents intermediate values for both peel strength and permeability, with an average permeability value of 8.1045×10^{-12} m².

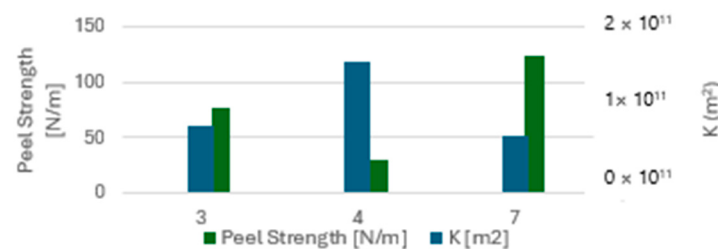


Figure 4. Relationship of peel strength vs permeability (K).

3.3. Mechanical Characterization

From all tested samples, coupons extracted from group 7 presented issues during testing. In the 0° direction, all coupons surpassed the percent bending strain (PBS), mainly due to the overall coupon thickness. In the 90° coupons (perpendicular to the fibers), no issues were presented (Table 5).

Table 5. Mechanical performance of coupons evaluated under compression.

Group	Maximum Load [kN]		Compression Strength [MPa]		Compression Modulus [GPa]		Peeling Strength [N/m]	Permeability [m ²]
	0°	90°	0°	90°	0°	90°		
3	30.09 ± 2.79	4.2 ± 0.32	1124.73 ± 88.65	154.4 ± 14.10	144.77 ± 1.78	9.1 ± 0.60	77.6 ± 13.5	$8.1045 \pm 1.05 \times 10^{-12}$
4	24.61 ± 4.15	3.51 ± 0.19	985.60 ± 179.51	145.30 ± 8.30	149.34 ± 5.08	8.2 ± 0.20	29.7 ± 12.10	$10.5661 \pm 9.63 \times 10^{-12}$
7	27.26 ± 5.96	4.61 ± 0.20	985.38 ± 196.07	163.3 ± 5.60	155.16 ± 13.93	9.1 ± 0.60	123.0 ± 14.7	$6.9188 \pm 4.82 \times 10^{-12}$

Compression modules are quite similar between the three groups in both directions. The 0° direction has no direct relationship with values of peeling strength. This could be related to the fact that some of the coupons presented a buckling tendency during testing. Similarly, there is no clear tendency on compression strength for the 0° direction. The 90° direction has a direct correlation with the peeling strength, following its tendency, but the final values between the groups are quite close.

4. Discussion

Heating power and deposition velocity affect directly the temperature of the tapes and their adhesion in the preform. Better peeling strength values were obtained at higher heating power rates and lower velocities, meaning that the material is heated longer during a longer time, ensuring more activation of the binder integrated into the material. Similar results are reported in previous studies [16,17]. Although this approach could not be interesting in an industrial environment, as commented on previously by A. Brasington et al. [18], priorities such as low manufacturing time/increased productivity must be defined. An analysis of advantages or disadvantages is necessary to ensure lower manufacturing times without affecting the final quality of the component to be manufactured. Compaction force is also important to consolidate the final material and ensure adhesion between layers; this is more relevant when thermoplastic or prepreg materials are used [19,20], but in this case, higher compaction forces affect the resulting preform permeability.

Higher permeability values were obtained when the peeling strength was lower, meaning less adhesion between layers. Loose fabrics allow the resin/fluid to flow more easily over the preform. Compression tests are not conclusive; in the 90° direction, it is possible to see a relationship between the adhesion quality and the final performance, but not a very significant one. More compression tests at 0° are necessary to establish a clear tendency. No further differences in quality were appreciated when performing micrography analysis over the coupons from the three groups; all samples presented low porosity values (<1%) and no visible defects. Comparable values of permeability were obtained for carbon fiber with similar characteristics [21–23].

The peeling test of the dry fibers gave an idea about the adhesion quality between layers as a result of the process parameters, since normally this depends on manual tests (trial and error) [24].

5. Conclusions

The heating power, deposition speed, and compaction force play critical roles in the adhesion and permeability properties of the preform in the AFP process. Higher heating power and deposition speed improved peel strength, although this might not be ideal for industrial environments due to the need to balance productivity and quality.

The peeling test provided valuable insights into the adhesion quality based on the influence of process parameters, offering a more systematic alternative. An inverse relationship between peel strength and permeability was determined. No significant differences were observed in the final quality of the samples, with porosity remaining below 1%. Additional compression tests are required to establish a clearer relationship between adhesion and mechanical values.

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References

1. Juarez, P.; Gregory, E. In Situ Thermal Inspection of Automated Fiber Placement for manufacturing induced defects. *Compos. Part B Eng.* **2021**, *220*, 109002. [CrossRef]
2. Marsh, G. Automating aerospace composites production with fibre placement. *Reinf. Plast.* **2011**, *55*, 32–37. [CrossRef]
3. Wanigasekara, C.; Oromiehie, E.; Swain, A.; Prusty, B.G.; Nguang, S.K. Machine learning-based inverse predictive model for AFP based thermoplastic composites. *J. Ind. Inf. Integr.* **2021**, *22*, 100197. [CrossRef]
4. Matveev, M.; Schubel, P.; Long, A.; Jones, I. Understanding the buckling behaviour of steered tows in Automated Dry Fibre Placement (ADFP). *Compos. Part A Appl. Sci. Manuf.* **2016**, *90*, 451–456. [CrossRef]
5. Liu, Y.-N.; Yuan, C.; Liu, C.; Pan, J.; Dong, Q. Study on the resin infusion process based on automated fiber placement fabricated dry fiber preform. *Sci. Rep.* **2019**, *9*, 7440. [CrossRef] [PubMed]
6. Veldenz, L. Automated Dry Fibre Placement and Infusion Process Development for Complex Geometries. University of Bristol, Bristol. 2019. Available online: <https://hdl.handle.net/1983/12a4e0bd-8275-4ebf-828d-702701b605cb> (accessed on 27 November 2024).
7. Matveev, M.; Ball, F.; Jones, I.; Long, A.; Schubel, P.; Tretyakov, M. Uncertainty in geometry of fibre preforms manufactured with Automated Dry Fibre Placement and its effects on permeability. *J. Compos. Mater.* **2017**, *52*, 2255–2269. [CrossRef]
8. Veldenz, L.; Di Francesco, M.; Astwood, S.; Dell’Anno, G.; Kim, B.C.; Potter, K. Characteristics and Processability of Binded Dry Fibre Material for Automated Fibre Placement. 2016. Available online: <https://research-information.bris.ac.uk/en/publications/characteristics-and-processability-of-binded-dry-fibre-material> (accessed on 3 December 2024).
9. Gharabegi, N. Composite Laminates Made by Automated Fiber Placement of Dry Fibers and Vacuum Assisted Resin Transfer Molding. Ph.D. Thesis, Concordia University, Montreal, QC, Canada, 2018.
10. Di Francesco, M.; Veldenz, L.; Dell’Anno, G.; Potter, K. Heater power control for multi-material, variable speed Automated Fibre Placement. *Compos. Part A Appl. Sci. Manuf.* **2017**, *101*, 408–421. [CrossRef]
11. Grisin, B.; Carosella, S.; Middendorf, P. Dry Fibre Placement: The Influence of Process Parameters on Mechanical Laminate Properties and Infusion Behaviour. *Polymers* **2021**, *13*, 3853. [CrossRef] [PubMed]
12. Su, Y.; de Rooij, M.; Grouve, W.; Warnet, L. Characterisation of metal–thermoplastic composite hybrid joints by means of a mandrel peel test. *Compos. Part B Eng.* **2016**, *95*, 293–300. [CrossRef]
13. Weidmann, F.; Ziegmann, G.; Wieser, J. A review of mode I dominant interfacial fracture toughness test methods of skin-core bonding for thermoplastic composite sandwich structures. *J. Thermoplast. Compos. Mater.* **2022**, *36*, 2643–2673. [CrossRef]
14. ASTM Standard D6641/D6641M–16; Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials Using a Combined Loading Compression (CLC) Test Fixture. ASTM International: West Conshohocken, PA, USA, 2016. [CrossRef]
15. ISO 4410-2023; Test Methods for the Experimental Characterization of in-Plane Permeability of Fibrous Rein-Forcements for Liquid Composite Moulding, International Organization for Standardization (ISO), Vernier, Switzerland. Available online: <https://www.iso.org/standard/79944.html> (accessed on 27 November 2024).
16. Khan, M.A.; Mitschang, P.; Schledjewski, R. Identification of some optimal parameters to achieve higher laminate quality through tape placement process. *Adv. Polym. Technol.* **2010**, *29*, 98–111. [CrossRef]
17. Belhaj, M.; Deleglise, M.; Comas-Cardona, S.; Demouveau, H.; Binetruy, C.; Duval, C.; Figueiredo, P. Dry fiber automated placement of carbon fibrous preforms. *Compos. Part B Eng.* **2013**, *50*, 107–111. [CrossRef]
18. Brasington, A.; Sacco, C.; Halbritter, J.; Wehbe, R.; Harik, R. Automated fiber placement: A review of history, current technologies, and future paths forward. *Compos. Part C Open Access* **2021**, *6*, 100182. [CrossRef]
19. Felderhoff, K.D.; Steiner, K.V. A New Compact Robotic Head for Thermoplastic Fiber Placement. *Adv. Mater. Perform. Through Technol. Inscr.* **1993**, *38*, 138–151. Available online: https://jglobal.jst.go.jp/en/detail?JGLOBAL_ID=200902189958781145 (accessed on 16 January 2025).
20. Del Castillo, D.S.; Martin, I.; Rodriguez-Lence, F.; Guemes, A. On-Line Monitoring of a Laser-Assisted Fiber Placement Process with CFR Thermoplastic Matrix by Using Fiber Bragg Gratings. Available online: <http://www.ndt.net/?id=20174> (accessed on 10 December 2024).

21. Gutierrez, A.; Mera, L.; Carral, L.; Coto, I.; Ansedes, F.; Pletting, M.; Renner, S. Automatization in New Manufacturing Approaches for Body Shell Applications. *Rev. Mater. Compuestos* **2023**, *7*. [[CrossRef](#)]
22. Poodts, E.; Minak, G.; Mazzocchi, L.; Giorgini, L. Fabrication, process simulation and testing of a thick CFRP component using the RTM process. *Compos. Part B Eng.* **2014**, *56*, 673–680. [[CrossRef](#)]
23. Baskaran Razkin, M. Optimización del proceso de Compression Resin Transfer Moulding (CRTM) Mediante Técnicas experimentales y Simulación. Ph.D. Thesis, Mondragon Unibertsitatea, Mondragón, Spain, 2017.
24. Endruweit, A.; De Focatiis, D.S.A.; Ghose, S.; Johnson, B.A.; Younkin, D.R.; Warrior, N.A. Characterization of Prepreg Tack to Aid Automated Material Placement. In *SAMPE Conference*; SAMPE: Long Beach, CA, USA, 2016.

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