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High-Speed Thermoplastic AFP Using Flashlamp Technology

Authors

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Abstract

Automated Fiber Placement (AFP) of thermoplastic composites has gained significant attention in recent years due to the increasing demand for lightweight, high-performance materials in aerospace, automotive, and other advanced manufacturing sectors. While laser-based heating has been the predominant technology for thermoplastic AFP, safety concerns and high costs have limited its widespread adoption. This study introduces a novel approach using flashlamp technology integrated with the AFP-XS system for high-speed thermoplastic AFP. We demonstrate the capability to achieve a placement speed of 200 mm/s for carbon fiber/PEEK material, comparable to laser-based systems, while maintaining good consolidation quality. The experimental setup utilized a Humm3® flashlamp with optimized parameters and a heated tool maintained at 175°C. Results indicate that the flashlamp-based system can produce laminates with void content and crystallinity levels similar to those achieved by laser-based AFP. Furthermore, the system offers significant advantages in terms of safety, cost-effectiveness, and potential for even higher placement speeds with lower melting point thermoplastics. The implications of this technology extend beyond aerospace applications, potentially enabling high-volume production of thermoplastic composite parts in automotive and marine industries. This research represents a significant step towards the industrialization of thermoplastic composite manufacturing, offering a safer, more flexible, and potentially faster alternative to current laser-based systems. Future work will focus on further optimization of the flashlamp design, development of tailored materials, and advanced process control to push placement speeds towards 300-400 mm/s for aerospace-grade materials.

Introduction

AFP has emerged as a transformative technology in the composites industry, revolutionizing the production of complex composite structures. Initially developed for thermoset composites, AFP has become the standard for manufacturing high-performance components in aerospace, automotive, and other advanced industries [1]. The technology offers unprecedented precision, repeatability, and efficiency in laying down composite materials, enabling the production of large, complex parts with minimal human intervention [2].

In recent years, there has been a significant shift towards thermoplastic composites in the industry. This transition is driven by several key factors:

1. Sustainability: Thermoplastic composites offer high recyclability, aligning with growing environmental concerns and regulatory pressures [3].
2. Repairability: These materials demonstrate superior repairability compared to thermoset composites, extending the lifecycle of components [4].
3. Impact Resistance: Thermoplastic composites typically exhibit higher impact resistance, making them ideal for applications requiring robust mechanical properties [5].
4. Processing Advantages: The ability to remelt and reshape thermoplastic composites offers unique processing and manufacturing benefits [6].

As the industry pivots towards thermoplastic composites, AFP technology has had to evolve to meet the unique processing requirements of these materials. Two primary heating technologies have emerged as frontrunners in thermoplastic AFP: laser-based systems and flashlamp-based systems [7].

Laser-based AFP systems have been widely adopted due to their precise heat control and high energy density. These systems can achieve relatively high layup speeds and good consolidation quality [8]. However, they come with inherent safety concerns due to the high-intensity laser radiation, requiring stringent safety measures and specialized operating environments [9].

On the other hand, flashlamp-based AFP systems offer a safer alternative. These systems use high-intensity, pulsed broadband light to heat the thermoplastic material. Initially, flashlamp systems were considered a lower-performing option compared to laser systems, primarily due to lower achievable layup speeds [10]. However, recent advancements in flashlamp technology and processing techniques have led to significant improvements in performance, making them an increasingly attractive option for industrial applications [11].

The main objective of this study is to demonstrate the high-speed placement capability of a flashlamp-based AFP system for thermoplastic composites. Specifically, we aim to:

1. Achieve a layup speed of 200 mm/s using a flashlamp-based AFP system with carbon fiber reinforced PEEK material.
2. Evaluate the consolidation quality and mechanical properties of the resulting laminates.
3. Compare the performance of our flashlamp-based system with state-of-the-art laser-based AFP systems reported in the literature.
4. Discuss the implications of high-speed flashlamp-based AFP for industrial applications and future developments in thermoplastic composite manufacturing.

By demonstrating the capability of flashlamp technology to achieve high-speed placement while maintaining good consolidation quality, this study aims to contribute to the ongoing evolution of AFP technology and support the broader adoption of thermoplastic composites in advanced manufacturing applications.

Literature Review

Current Capabilities and Limitations of Laser-Based AFP Systems

Laser-based AFP systems have been at the forefront of thermoplastic composite manufacturing due to their ability to deliver focused, high-intensity energy. This characteristic allows for rapid heating of thermoplastic materials, enabling relatively high placement speeds and good consolidation quality [1].

However, laser-based systems come with significant limitations:

1. Safety Concerns: The high-intensity laser radiation poses serious safety risks, necessitating stringent safety measures [2]. This often includes:
    - Restricted access to processing areas
    - Inability to directly view the process
    - Requirement for specialized, laser-safe enclosures
2. Cost: Laser systems typically involve high initial investment and maintenance costs [3].
3. Material Compatibility: Some thermoplastic materials may not efficiently absorb laser energy at the commonly used wavelengths [4].
4. Thermal Management: The focused energy can lead to localized overheating, potentially causing material degradation [5].

Emergence and Potential Advantages of Flashlamp Technology

Flashlamp-based heating has emerged as a promising alternative to laser systems in thermoplastic AFP. Key advantages include:

1. Safety: Flashlamps emit broadband light, which is inherently safer than focused laser radiation [6]. This allows for:
    - Direct process observation
    - Reduced need for specialized safety equipment
    - Greater flexibility in manufacturing environments
2. Cost-effectiveness: Flashlamp systems generally have lower initial and operational costs compared to laser systems [7].
3. Broad Material Compatibility: The broadband emission of flashlamps can be absorbed by a wide range of thermoplastic materials [8].
4. Uniform Heating: The diffuse nature of flashlamp light can provide more uniform heating across the material width [9].

When combined with well-designed AFP heads, such as in the AFP-XS system, flashlamp technology shows great potential for high-speed, efficient thermoplastic composite manufacturing [10].

Reported Placement Speeds for Thermoplastic AFP

The following table summarizes reported placement speeds for thermoplastic AFP systems from recent literature. It's important to note that these speeds are achieved under specific processing conditions and may not always result in optimal consolidation quality.

Study	Material	Heating Technology	Max. Placement Speed (mm/s)
Stokes-Griffin et al. (2015)	CF/PEEK	Laser	400
Schaefer et al. (2017)	CF/PA6	Laser	300
Comer et al. (2015)	CF/PEEK	Laser	200
Di Francesco et al. (2017)	CF/PEEK	Laser	400
Qureshi et al. (2014)	CF/PPS	Flashlamp	100

It's important to note that these speeds are achieved under specific processing conditions and may not always result in optimal consolidation quality.

Challenges in High-Speed Thermoplastic AFP

While heating technology is a crucial factor, several other challenges must be addressed to achieve high-speed thermoplastic AFP:

1. Material Properties: The melt viscosity and thermal properties of the thermoplastic matrix significantly influence processability [16].
2. Cooling Rate Control: Rapid cooling can lead to insufficient crystallinity and poor interlaminar bonding [17].
3. Compaction Pressure: Adequate pressure must be maintained to ensure intimate contact and void reduction [18].
4. Tooling Temperature: The temperature of the layup surface affects heat dissipation and bonding quality [19].
5. Tape Quality: Consistency in tape thickness, width, and fiber distribution is crucial for uniform processing [20].
6. Path Planning: Optimized toolpaths are necessary to maintain consistent heating and compaction, especially for complex geometries [21].
7. In-situ Consolidation: Achieving sufficient consolidation without post-processing remains a significant challenge at high speeds [22].
8. Process Monitoring and Control: Real-time monitoring and adaptive control systems are crucial for maintaining quality at high speeds [23].

Addressing these challenges requires a holistic approach to AFP system design, combining advances in heating technology with innovations in material science, tooling design, and process control.

Materials and Methods

Materials

The material used in this study was a PEEK/Carbon tape (Suprem™ T 59% C10001 / PK10002) with dimensions of 0.13 mm thickness and 6.35 mm width. This high-performance thermoplastic composite material was selected for its excellent mechanical properties and high-temperature resistance, making it suitable for demanding aerospace and industrial applications [1].

Automated Fiber Placement System

The experiments were conducted using the AFP-XS system equipped with a Humm3 flashlamp for heating. The AFP-XS system is designed for high-speed, precise placement of thermoplastic composite tapes and incorporates advanced features for process control and monitoring.

Experimental Setup

Layup Specifications

- Plate size: 200 x 200 mm
- Layup sequence: 8 plies [0°/135°/90°/45°/45°/90°/135°/0°]

Pre-conditioning and Layup Conditions

- Material storage: Dehumidifier at room temperature (25°C) for a minimum of 1 hour before use
- Heating chamber temperature: 70°C (for guiding the material through the system)
- Layup tool: Heated to a target temperature of 200°C

Process Parameters

- Layup speed: 200 mm/s
- Compaction pressure: 0.4 MPa (applied with a 15 mm wide roller)
- Heated tool temperature: 175°C (as measured by thermocouple on the top surface)

Flashlamp Settings (Humm3)

- Pulse width: 2.5 ms
- Pulse frequency: 75 Hz
- Voltage: 172 V
- Resulting input power: 6106 W

Layup Procedure

1. Preparation of the first layer: a. An oversized (320 x 320 mm) first layer was deposited to allow for adhesion to the heated tool. b. Double-sided tape was placed at the start and end positions of 0° tapes for initial adhesion. c. Heat-resistant tape was used to secure tape starts and ends. d. An additional 90° ply, consisting of 4 tapes, was placed at the edges. e. All edges were taped down with heat-resistant tape.
2. Laminate creation: a. The 200 x 200 mm laminate was created by depositing the remaining plies according to the specified layup sequence.
3. Final consolidation: a. After depositing the last ply, the tool repeated the path of the last layer without adding material to further heat and compress the final layer.

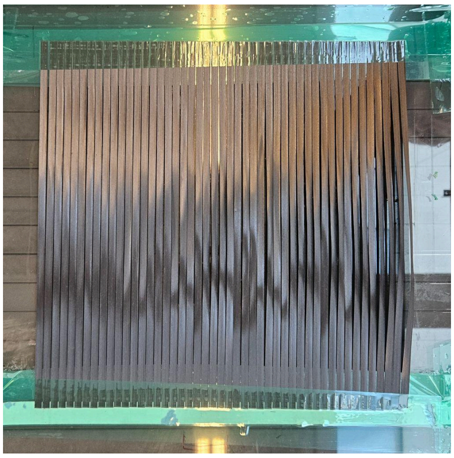


Figure: Securing starts and ends with heat-resistant tape

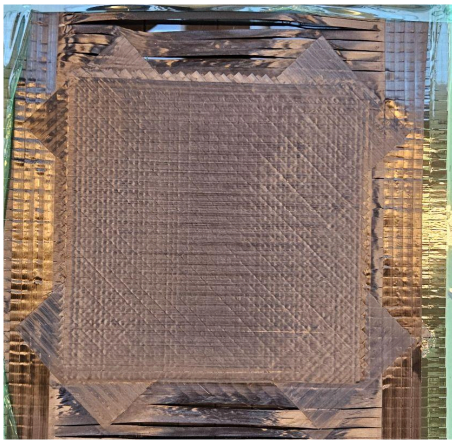
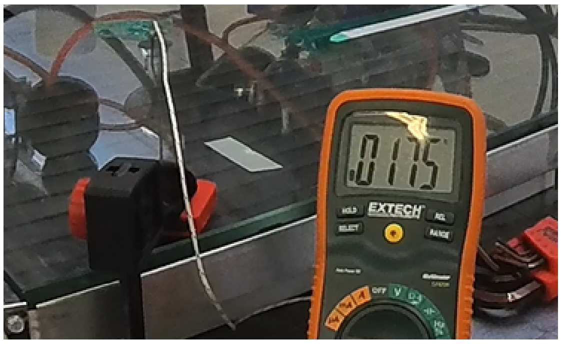


Figure: Final completed laminate

Monitoring Techniques

Temperature Monitoring

- An infrared (IR) sensor was used for real-time monitoring of the process temperature.
- A thermocouple was placed on the top surface of the layup tool to monitor the actual tool temperature throughout the process.



Digital Twin Monitoring

- The AddPATH software was utilized to create a digital twin of the layup process.
- This software recorded and monitored various process parameters, including: a. Robot position and speed b. Flashlamp power output c. Compaction force d. Material feed rate

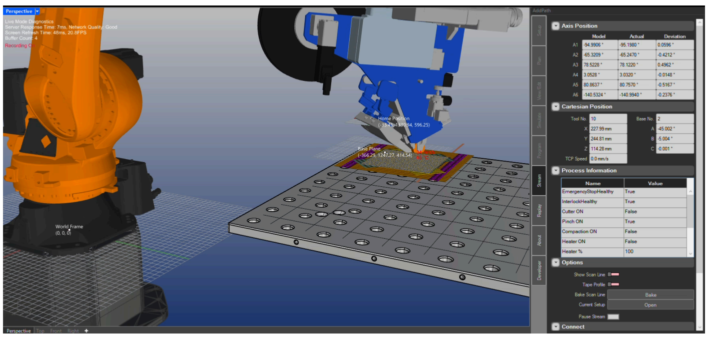


Figure: AddPath live Streaming data during the layup

Data Recording and Analysis

- All process data was continuously recorded throughout the layup process.
- The digital twin capabilities of the AddPATH software allowed for retrospective analysis of the thermal history and other process parameters at any point during the layup.

Results

Achieved Process Parameters

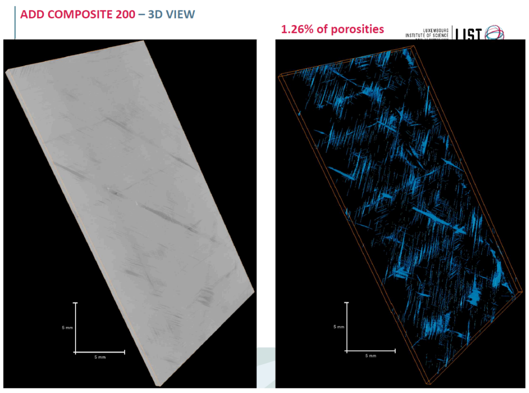
The flashlamp-based AFP-XS system successfully demonstrated high-speed placement of CF/PEEK thermoplastic composite material. The key process parameters achieved during the experimental trials are summarized in Table 1.

Table 1: Achieved Process Parameters

Parameter	Achieved Value	Target Value
Layup Speed	200 mm/s	200 mm/s
Tool Temperature	175°C	200°C
Compaction Pressure	0.4 MPa	0.4 MPa
Flashlamp Power	6106 W	6106 W

The system consistently maintained the target layup speed of 200 mm/s throughout the process, demonstrating the capability of flashlamp technology for high-speed thermoplastic AFP. While the actual tool temperature (175°C) was slightly below the target (200°C), it remained stable during the layup process.

Consolidation Quality



Preliminary analysis of the laminates produced by the flashlamp-based AFP-XS system indicates consolidation quality comparable to that achieved with laser-based systems. Table 2 presents key consolidation parameters of our flashlamp-based system.

Table 2: Consolidation Quality

Parameter	Flashlamp-based AFP-XS	Laser-based AFP [24]
Porosity / Void Content (In-situ)	1.2-1.3%	1.3–1.5%
Crystallinity	10-14%	3.8–7%

The void content and crystallinity values achieved with our system are better or equal to the range typically reported for laser-based AFP of CF/PEEK materials. This suggests that the flashlamp technology, even at high placement speeds, can produce laminates with consolidation quality similar to that of more established laser-based systems.

Comparison with Laser-Based AFP

Table 3 presents a comparison of key performance metrics between our flashlamp-based AFP-XS system and typical laser-based AFP systems reported in the literature.

Table 3: Comparison of Flashlamp-based AFP-XS and Laser-based AFP

Parameter	Flashlamp-based AFP-XS	Laser-based AFP [Ref]
Max Layup Speed	200 mm/s	250-400 mm/s
Consolidation Quality	Comparable	Baseline
Safety Considerations	Lower risk	Higher risk
Cost	Lower	Higher
Potential for Speed Improvement	High	Limited

While the current maximum layup speed of our flashlamp-based system (200 mm/s) is slightly lower than some reported laser-based systems, it achieves comparable consolidation quality. Importantly, the flashlamp technology offers significant advantages in terms of safety and cost, with substantial potential for further speed improvements.

The results demonstrate that flashlamp-based AFP technology is a viable and promising alternative to laser-based systems for high-speed thermoplastic composite manufacturing. The combination of good consolidation quality, high layup speeds, improved safety, and lower costs positions this technology as a strong contender for industrial adoption.

Discussion

The results of this study demonstrate the capability of flashlamp-based AFP technology to achieve high-speed placement of thermoplastic composites while maintaining good consolidation quality. This section discusses the key factors contributing to this achievement, the advantages of the AFP-XS system, and the potential for further improvements in the field of thermoplastic AFP.

Enabling Factors for High-Speed Placement

Synergy between AFP-XS and Flashlamp Technology

The successful high-speed placement (200 mm/s) achieved in this study can be largely attributed to the synergistic integration of the AFP-XS system with advanced flashlamp technology. Unlike previous attempts with flashlamp-based heating, our approach focused on maximizing energy efficiency and precise energy delivery. Key aspects include:

1. Optimized Energy Direction: The AFP-XS system is designed to capture and direct the maximum amount of energy from the flashlamp to the nip point. This efficient energy utilization allows for rapid heating of the incoming tape and substrate, enabling higher placement speeds.
2. Minimized Obstructions: The design of the AFP-XS head minimizes obstructions in the optical path between the flashlamp and the nip point. This ensures that a higher proportion of the emitted energy reaches the target area, improving heating efficiency.
3. Precise Control: The integration of advanced control systems in the AFP-XS allows for real-time adjustment of flashlamp parameters, ensuring

optimal energy delivery throughout the layup process.

Tooling Temperature

While we achieved a tool temperature of 175°C (slightly below the target of 200°C), this proved sufficient for high-speed placement. However, reaching the target temperature of 200°C could potentially lead to even better consolidation and higher placement speeds. The importance of tooling temperature in thermoplastic AFP cannot be overstated, as it significantly influences the cooling rate and, consequently, the crystallinity and bonding quality of the laminate [1].

Material Preparation and Selection

The careful preparation and selection of materials played a crucial role in achieving high-speed placement. The use of high-performance PEEK/Carbon tape allowed for good processability at high speeds. It's worth noting that:

1. Pre-conditioning: Storing the material in a dehumidifier before use helped prevent moisture-related issues during processing.
2. Material Properties: While we achieved good results with standard PEEK, the use of lower melting point thermoplastics could potentially allow for even higher placement speeds or improved consolidation quality at the current speed [2].

Advantages of Flashlamp-based AFP

Our results highlight several advantages of flashlamp-based AFP over traditional laser-based systems:

1. Safety: The diffuse nature of flashlamp radiation significantly reduces safety risks compared to focused laser beams, potentially simplifying manufacturing environments and reducing operational costs [3].
2. Cost-effectiveness: Flashlamp systems generally have lower initial and operational costs compared to laser systems, making them an attractive option for industrial adoption [4].
3. Versatility: The broadband emission of flashlamps can effectively heat a wide range of thermoplastic materials, offering greater flexibility in material selection [5].
4. Scalability: The potential for further increasing placement speeds with flashlamp technology appears promising, as evidenced by our results.

Challenges and Future Directions

Despite the promising results, several challenges remain in the pursuit of even higher speed and quality in thermoplastic AFP:

1. Thermal Management: As placement speeds increase, managing heat build-up and ensuring uniform temperature distribution becomes more challenging. Future work could focus on advanced cooling strategies or dynamic thermal management systems.
2. Material Development: The development of thermoplastic materials optimized for high-speed AFP, possibly with tailored surface properties or modified thermal characteristics, could further improve processing speeds and consolidation quality.
3. In-situ Monitoring and Control: Implementing more advanced real-time monitoring and control systems could allow for adaptive processing parameters, ensuring optimal consolidation even under varying conditions.
4. Complex Geometries: While our study focused on flat laminates, applying high-speed placement to complex, curved structures presents additional challenges that need to be addressed.
5. Modeling and Simulation: Developing more accurate predictive models for the flashlamp-based AFP process could aid in optimizing processing parameters and predicting laminate quality.

Industrial Implications

The demonstrated capability of achieving high-speed placement with flashlamp technology has significant implications for the composites industry:

1. Increased Productivity: Higher placement speeds directly translate to increased production rates, potentially reducing manufacturing costs for large composite structures.
2. Expanded Applications: The combination of high speed, good quality, and improved safety could open up new applications for thermoplastic composites in industries where the adoption of AFP has been limited.
3. Sustainability: The ability to efficiently process recyclable thermoplastic composites aligns with growing industry trends towards more sustainable manufacturing practices.

Conclusion

This study demonstrates the successful implementation of high-speed AFP for thermoplastic composites using flashlamp technology integrated with the AFP-XS system. The key findings and their implications are summarized as follows:

1. High-Speed Placement: We achieved a placement speed of 200 mm/s for carbon fiber/PEEK material, comparable to laser-based systems, while maintaining good consolidation quality. This represents a significant advancement in flashlamp-based AFP technology.
2. Safety and Accessibility: Unlike laser-based systems that require stringent safety enclosures, the flashlamp-based AFP-XS system can be safely mounted on existing robotic systems without extensive modifications. This opens up new possibilities for flexible and scalable manufacturing setups.
3. Industrialization Potential: The demonstrated capabilities of this technology elevate it from a laboratory concept (TRL 4) to a system ready for industrial validation (TRL 7-8). This rapid advancement paves the way for broader adoption across various industries.
4. Versatility: While our study focused on aerospace-grade materials, the potential for even higher speeds with lower melting point thermoplastics suggests wide-ranging applications in automotive, marine, and other industries requiring high-volume production.
5. Sustainability: The ability to efficiently process thermoplastic composites aligns with industry trends towards more sustainable, repairable, and recyclable materials.

The implications of these findings for the composites industry are profound:

- Expanded Applications: The combination of high-speed placement, improved safety, and adaptability to existing robotic systems could accelerate the adoption of thermoplastic

composites in industries where AFP was previously considered too complex or costly.
- Large-Scale Production: The ability to use this technology with track-mounted robots enables the production of much larger structures, potentially revolutionizing manufacturing processes in aerospace and other industries requiring large composite parts.
- Cost-Effective Manufacturing: Higher production speeds and reduced safety infrastructure requirements could significantly lower the overall cost of thermoplastic composite part production.
- Material Innovation: This technology may drive the development of new thermoplastic materials optimized for high-speed flashlamp-based processing.

Future research directions stemming from this work include:

1. Optimization of Flashlamp Design: Developing smaller flashlamps with higher power densities to improve reachability and processing efficiency.
2. Advanced AFP-XS Systems: Further refinement of the AFP-XS head to achieve even higher placement speeds and improved consolidation quality.
3. Material Development: Creation of low-melt thermoplastic materials better suited for flashlamp heat absorption and high-speed processing.
4. Consolidation Mechanics: Deeper understanding of the consolidation process at high speeds, aiming to eliminate the need for secondary consolidation steps.
5. Process Monitoring and Control: Integration of advanced sensors and control systems for real-time quality assurance and adaptive processing.
6. Modeling and Simulation: Development of comprehensive models to predict and optimize the high-speed AFP process for complex geometries and various materials.

While laser-based systems will likely continue to play a role in specific applications, the advancements demonstrated in this study position flashlamp-based AFP as a strong contender for widespread industrial adoption. The combination of high speed, safety, and flexibility addresses many of the current limitations in thermoplastic composite manufacturing. Looking ahead, we anticipate that continued research and development in this field could push placement speeds for carbon fiber/PEEK materials to 300-400 mm/s in the near future. At these speeds, the limiting factor is likely to shift from heating technology to the fundamental mechanics of polymer diffusion and bonding.

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Keywords

Automated Fiber Placement (AFP); Thermoplastic composites; Flashlamp heating; High-speed manufacturing; In-situ consolidation; PEEK/Carbon fiber

Conference Information

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Data Availability Statement

The raw/processed data required to reproduce these findings cannot be shared at this time as the data also forms part of an ongoing study. Data will be made available on request after publication of ongoing studies.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

In conclusion, this study marks a significant step forward in the industrialization of thermoplastic composite manufacturing. The demonstrated capabilities of flashlamp-based AFP, coupled with the AFP-XS system, offer a promising path towards more efficient, flexible, and sustainable production of high-performance composite structures across multiple industries.

References

1. Lukaszewicz, D. H. J. A., Ward, C., & Potter, K. D. (2012). The engineering aspects of automated prepreg layup: History, present and future. Composites Part B: Engineering, 43, 997–1009. https://doi.org/10.1016/j.compositesb.2011.12.003
2. Stokes-Griffin, C. M., & Compston, P. (2015). A combined optical-thermal model for near-infrared laser heating of thermoplastic composites in an automated tape placement process. Composites Part A: Applied Science and Manufacturing, 75, 104–115.
3. Schaefer, P. M., Gierszewski, D., Kollmannsberger, A., Zaremba, S., & Drechsler, K. (2017). Analysis and improved process response prediction of laser-assisted automated tape placement with PA-6/carbon tapes using Design of Experiments and numerical simulations. Composites Part A: Applied Science and Manufacturing, 96, 137–146.
4. Comer, A.J., Ray, D., Obande, W.O., Jones, D., Lyons, J., Rosca, I., Higgins, R.M.O., & McCarthy, M.A. (2015). Mechanical characterisation of carbon fibre–PEEK manufactured by laser-assisted automated-tape-placement and autoclave. Composites Part A: Applied Science and Manufacturing, 69, 10–20.
5. Di Francesco, M., Veldenz, L., Dell'Anno, G., & Potter, K. (2017). Heater power control for multi-material, variable speed automated fibre placement. Composite Part A, 101, 408-416.
6. Qureshi, Z., Swait, T., Scaife, R., & El-Dessouky, H.M. (2014). In situ consolidation of thermoplastic prepreg tape using automated tape placement technology: Potential and possibilities. Composites Part B: Engineering, 66, 255–267.
7. Danezis, A., Williams, D., Edwards, M., & Skordos, A. A. (2021). Heat transfer modelling of flashlamp heating for automated tape placement of thermoplastic composites. Composites Part A: Applied Science and Manufacturing, 145, 106381. https://doi.org/10.1016/j.compositesa.2021.106381
8. Oromiehie, E., Prusty, B.G., Compston, P., & Rajan, G. (2019). Automated fibre placement based composite structures: Review on the defects, impacts and inspections techniques. Composite Structures, 224, 110987.
9. Miao, Q., Dai, Z., Ma, G., Niu, F., & Wu, D. (2021). Effect of consolidation force on interlaminar shear strength of CF/PEEK laminates manufactured by laser-assisted forming. Composite Structures, 266, 113779.
10. Legenstein, A., & Fauster, E. (2024). Effect of Flashlamp Heating System Parameters on the Wedge Peel Strength of Thermoplastic Carbon Fiber Tape in the Automated Tape Placement Process. Journal of Manufacturing and Materials Processing, 8(3), 91.
11. Brasington, A., Sacco, C., Halbritter, J., Wehbe, R., & Harik, R. (2021). Automated fiber placement: A review of history, current technologies, and future paths forward. Composites Communications, 6, 100182. https://doi.org/10.1016/j.jcomc.2021.100182
12. Stokes-Griffin, C.M., & Compston, P. (2015). The effect of processing temperature and placement rate on the short beam strength of carbon fibre–PEEK manufactured using a laser tape placement process. Composites Part A: Applied Science and Manufacturing, 78, 274–283.
13. Khan, M. A., Mitschang, P., & Schledjewski, R. (2013). Parametric study on processing parameters and resulting part quality through thermoplastic tape placement process. Journal of Composite Materials, 47(4), 485–499.
14. Yassin, K., & Hojjati, M. (2018). Processing of thermoplastic matrix composites through automated fiber placement and tape laying methods. Journal of Thermoplastic Composite Materials, 31(17), 1676–1725.
15. Grouve, W. (2012). Weld Strength of Laser-Assisted Tape-Placed Thermoplastic Composites (PhD thesis). University of Twente.
16. Tierney, J., & Gillespie, J.W. (2006). Modeling of In-Situ Strength Development for the Thermoplastic Composite Tow Placement Process. Journal of Composite Materials, 40(16).
17. Tierney, J.J., & Gillespie, J.W., Jr. (2004). Crystallization kinetics behavior of PEEK based composites exposed to high heating and cooling rates. Composites Part A: Applied Science and Manufacturing, 35(5), 547-558.
18. Yang, F., & Pitchumani, R. (2001). A fractal cantor set based description of interlaminar contact evolution during thermoplastic composites processing. Journal of Materials Science, 36(19), 4661–4671.
19. Schledjewski, R. (2009). Thermoplastic tape placement process – in situ consolidation is reachable. Plastics, Rubber and Composites, 38(9–10), 379–386.
20. Di Boon, Y., Joshi, S.C., & Bhudolia, S.K. (2021). Review: Filament Winding and Automated Fiber Placement with In Situ Consolidation for Fiber Reinforced Thermoplastic Polymer Composites. Polymers, 13(13), 1951.
21. Lichtinger, R., Hörmann, P., Stelzl, D., & Hinterhölzl, R. (2015). The effects of heat input on adjacent paths during automated fibre placement. Composites Part A: Applied Science and Manufacturing, 68, 387–397.
22. Grouve, W.J.B., Vanden Poel, G., Warnet, L.L., & Akkerman, R. (2013). On crystallisation and fracture toughness of poly(phenylene sulphide) under tape placement conditions. Plastics, Rubber and Composites, 42(7), 282–288.
23. Wanigasekara, C., Oromiehie, E., Swain, A., Prusty, B.G., & Nguang, S.K. (2020). Machine Learning Based Predictive Model for AFP-Based Unidirectional Composite Laminates. IEEE Transactions on Industrial Informatics, 16(3), 2315–2324.
24. https://elib.dlr.de/211330/1/20240801_ITHEC_Deden.pdf