UNION OF ENGINEERS AND TEXTILE
TECHNICIANS OF SERBIA

V INTERNATIONAL SCIENTIFIC CONFERENCE

# CONTEMPORARY TRENDS AND INNOVATIONS IN THE TEXTILE INDUSTRY

V MEĐUNARODNA NAUČNA KONFERENCIJA

# SAVREMENI TRENDOVI I INOVACIJE U TEKSTILNOJ INDUSTRIJI

## PROCEEDINGS

EDITOR:
Prof. dr SNEŽANA UROŠEVIĆ

Belgrade, 15-16th September, 2022.
Union of Engineers and Technicians of Serbia
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V INTERNATIONAL SCIENTIFIC CONFERENCE
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UNION OF ENGINEERS AND TEXTILE TECHNICIANS OF SERBIA

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FACULTY OF TECHNOLOGY AND METALLURGY IN BELGRADE
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**Union of Engineering and Technicians of Serbia**

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# PREFACE

The 5 th International conference "Contemporary Trends and Innovations in the Textile Industry" CT&ITI 2022, is co-organized by the Union of Engineers and Textile Technicians of Serbia, the Union of Engineers and Technicians of Serbia, the Faculty of Technology and Metallurgy in Belgrade, the University of Faculty of Technology, Shtip, North of Macedonia, Society for Robotics of Bosnia i Herzegovina and Balkan Society of Textile Engineering-BASTE of Greece.

The Ministry of Education, Science and Technological Development of the Republic of Serbia recognized the importance of this Conference, and thus, supported it.

The aim of this Conference is to consider current technical, technological, economic, ecological, R&D, legal and other issues related to the textile industry, then the application of contemporary achievements and the introduction of technical and technological innovations in the production process of fiber, textile, clothing and technical textile by applying scientific solutions in order to improve the business and increase the competitive advantages of the textile industry on the domestic and global market.

Leading scientists and experts from the Balkans and other countries, working at faculties, textile colleges and institutes, but also individuals who professionally deal with the issues at hand are taking part in this Conference.

The Conference program involves papers dedicated to the scientific and practical aspects of the following topics: Textile and Textile Technology, Textile Design, Management and Marketing in the Textile Industry and Ecology and Sustainable Development in the Textile Industry. The Conference program includes 48 papers, and a total of 116 participants from 14 countries: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, India, Latvia, North of Macedonia, Portugal, Romania, Russia, Serbia, Slovenia and Turkey.

Therefore, this Conference is an opportunity for establishing scientific, educational and economic cooperation of our country with other countries. Certain number of papers by domestic authors present the project results dealing with fundamental research and technological development, financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

I would like to thank all those who have made it possible to organize the conference Contemporary Trends and Innovations in the Textile Industry and make it a success. First, I would like to thank the Scientific and Organizing Committee for working hard, spending countless hours and finding the best solutions for numerous organizational aspects of our Conference. Also, I would like to express my gratitude to all sponsors who believed in the importance of this Conference and co-financed it. I also thank all the other institutions that supported the Conference in various ways, because without their support, the Conference could not have been organized. Last but not least, I would like to thank plenary lecturers, all authors and co-authors and guests for their participation in the Conference.

On behalf of the Organizing Committee
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# AUTOMATED FIBER PLACEMENT TECHNOLOGY OVERVIEW

**Sara Srebrenkoska[1*], Marija Cekerovska[1]**

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**ABSTRACT:** *In this paper automatic fiber placement method is presented. This literature reviews the entire AFP process from the design of the structure through inspection of the manufactured part to generate an overall understanding of the lifecycle of AFP manufacturing. Also, typical materials dedicated for AFP technology are presented. The advantages and limitations of various system configurations in terms of parts size, parts shape and composite materials are discussed.*

**Keywords:** *fiber, technology, composite*

# PREGLED TEHNOLOGIJE AUTOMATSKE INSTALACIJE VLAKANA

**APSTRAKT:** *U ovom radu je prikazan metod automatskog postavljanja vlakana. Ova literatura daje pregled čitavog procesa AFP od dizajna strukture do inspekcije proizvedenog dela kako bi se stvorilo opšte razumevanje životnog ciklusa proizvodnje AFP. Takođe, predstavljeni su tipični materijali namenjeni AFP tehnologiji. Razmatraju se prednosti i ograničenja različitih konfiguracija sistema u pogledu veličine delova, oblika delova i kompozitnih materijala.*

**Ključne reči:** *vlakno, tehnologija, kompozit*

## 1. INTRODUCTION

Automated fiber placement (AFP) is a composite manufacturing technique used to fabricate complex advanced air vehicle structures that are lightweight with superior qualities. The AFP process is intricate and complex with various phases of design, process planning, manufacturing, and inspection. An understanding of each of these phases is necessary to achieve the highest possible manufacturing quality. The idea of automatic Fiber Placement technology is to lay composite layer with 0,25" width

unidirectional prepreg tape. Each single tape is laid down by a robotic system with butt joint. Each layer can be laid with different orientation, which benefits a structure capable to carry load in the required direction. Each tape is pressed to the mould by a roller for proper compaction. (Figure 1), [1].

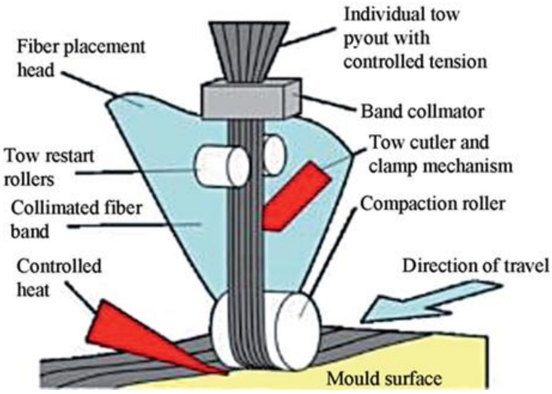


**Figure 1**: Automatic Fiber Placement head laying prepreg tape onto the mould [coriolis composites, 2015]

### 1.1. AUTOMATIC FIBER PLACEMENET SYSTEM ARCHITECTURE

The AFP systems are typically individually suited for a particular application, however, each of those systems has a typical subcomponent. These are:

1. Head with compaction roller;
2. Fiber feeding system;
3. Robotic arm;
4. Control panel.

Typical AFP system subcomponents are shown in Figure 2, [2].

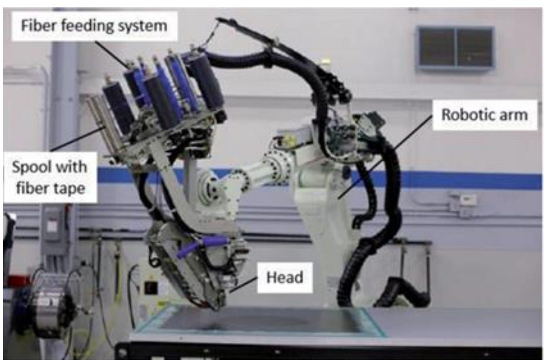


**Figure 2:** Automatic Fiber Placement system subcomponents [Automated Dynamics, 2015]

There are three main types of AFP machines: horizontal gantry, vertical gantry, and robotic arm. The type of machine to be used is dependent on the size and shape of the part. Large plate-like structures are good candidates for the gantry type of machine, especially the vertical gantry, because they do not require complex motion. Horizontal gantries are usually preferred when the tool has a large height or needs to be rotated because the gantry structure does not hinder the tool. However, the robotic arm type of machine will be beneficial for complex shapes because it has a wider range of motion to maneuver around higher curvatures (Figure 3).

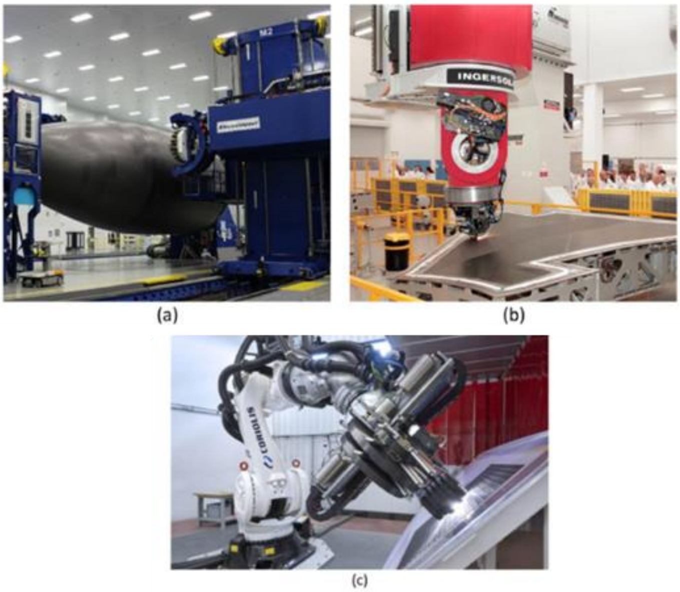


**Figure 3:** Images of (a) horizontal gantry [3], (b) vertical gantry [4], and (c) robotic arm type AFP machines [5].

## 2. EXPERIMENTAL

Material choice can lead to adverse or beneficial effects on the manufacturing process along with the final overall quality.
Commercially available AFP systems can work with 3 types of composite materials:
1. Thermoset fiber;
2. Thermoplastic fiber;
3. Dry fiber (unsaturated).

Thermosets and thermoplastics are referred to as “prepreg” because the fibers are already pre-impregnated with resin, while dry fiber is not. Each of these comes with its own processing range and technique which are explained in the latter. Table 1 below provides a summary with key characteristics of each material.

**Table 1:** Characteristics of each material type

| Material | Processing Temperature | Material Storage | Curing |
|---|---|---|---|
| Thermoset | Low | Frozen | Autoclave/Oven |
| Thermoplastic | High | Room Temp | *In-situ*/Autoclave |
| Dry Fiber | High | Room Temp | Infusion |

Each material is supplied on a standard spool as a unidirectional tape, the most common tape width is 0.25” and 0.5” for large structures [6]. The most common material system used for aerostructure build are thermoset materials, which is also reflected in AFP technology.

Thermoset prepregs utilize a combination of fibers and thermoset resins. Thermoset resins are polymer resins with a relatively low viscosity, and when cured form a rigid 3D lattice structure [7]. An example of thermoset material is Hexcel 855aS4 tape. In addition, thermoset tapes require a secondary processing step, such as autoclave consolidation, increasing processing time and cost [8].

New generation AFP systems are equipped with a laser heat source to allow thermoplastic materials processing. Thermoplastic prepreg materials use a combination of fibers and thermoplastic resin. These types of resins have a high viscosity and do not chemically join, or cure, when heated meaning they can go through solid and fluid transformations many times [7]. Thermoplastics are beneficial as they have many advantages over thermosets including recyclability, rework ability, high temperature performance, high impact resistance, and long shelf life at room temperature [8]. Furthermore, these materials bring about the possibility of skipping a post consolidation step such as an autoclave, oven, or hot-press by using in-situ consolidation [[9], [10], [11]]. However they are difficult to layup due to higher required temperatures (typically around 400 °C [12]) and smaller operating processing window [13].

An example of thermoplastic tape is cytec APc2-34-AS4.

AFP system producers also developed processes to support infusion and resin transfer moulding (RTM) fabrication. Dry fiber materials, just as they sound, do not contain a resin matrix. Similar to thermoplastics, dry fiber layup requires higher temperatures and has a small operating window [14]. Dry fiber has a long shelf life at room temperature, and lends itself to steering application since it is easier to steer as there is no matrix confining the fibers, allowing the tow to bend or shear [15]. However, dry tows do not have tackiness so a vail (thin thermoplastic layer) is required to allow lay-up of the tows [16]. An example of dry fiber AFP tape is CYCOM 7720 binder coated fabric.

## 3. RESULT AND DISCUSSION

The main advantages of AFP system are as follows:

1. Producibility;
2. Fiber direction accuracy, [17];
3. Part to part repetability;
4. Low amount of material waste.

Industrial AFP system can be equipped with multi tow heads to increase layup speed. There is no necessity to prepare plies flat patterns like for hand layup, also de-bulking (a process used while composite hand layup to apply vacuum bag every couple of composite layers for better plies nesting and removing unnecessary air contaminated between prepreg plies operations) can be limited or removed from the process. All of that reduces fabrication cost.

AFP system layup of composite tapes is accordant to the defined tape path. In the case when mould geometry enforces tape direction changes, it is known before a part is made. After optimization of AFP program for a particular part, each part is manufactured in the same way and operator to operator variation is eliminated.

Very important advantages of AFP method is a low amount of material waste. comparing to hand layup where each ply shape is cut from material roller creating larger amount of waste material, AFP system just cuts each tape and restarts it in the area where it is needed.

Automatic fiber placement system has also several disadvantages and limitations. Typical limitations are related to the mould shape. compaction roller diameter and head geometry limits female mould radiuses that can be used for parts built with this technology. Other disadvantages are related to ply edges created by cut tapes. This is not a problem on part edges which are typically trimmed, however, in local composite build ups sawblade shape ply contour, (figure 4) is a phenomenon that a designer needs to accept [1].

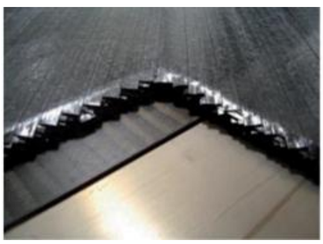

**Figure** 4: Ply edge with characteristic sawblade contour obtained by AFP process [coriolis composites, 2015]

## 4. CONCLUSION

Since AFP's industrial start in the 1980's, it has continually advanced to become a leading manufacturing technique for large composite structures. Early advancements in the realms of process reliability and productivity lead the way for the adoption of this technique within many aerospace companies. With review of the intricacies of each pillar of the AFP process, it is evident that progress has not stalled. Expertise ranging from composite design through inspection provides a deep understanding of the AFP process. This knowledge has produced the state-of-the-art technologies that are presented here. Overall productivity and reliability are still on the rise as AFP enters the realm of future manufacturing.
AFP technology significantly reduces time of a part manufacturing, 8 tow head machine can reduce 20 times layup time in comparison with hand layup.
This technology ensures parts repeatability, especially in the field of fiber direction and fiber trim. Although AFP technology with thermoset materials was successfully introduced into production, the usage of AFP technology with thermoplastic composites is still on the preliminary phase. AFP system equipped with a laser heat source allows to conduct r&D work with thermoplastic tape and in-situ fabrication. combination of AFP method cost advantages and thermoplastic composite material properties advantages can be very beneficial.

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