# CHAPTER 1

# General Introduction

# Ⅰ.General Introduction

Over the years, a great deal of interest has been given to the nickel coated carbon fibers used as functional and reinforced materials in plastic, glass and metal matrix composites [1-4]; however, the chemical reactions and wettability between the carbon fiber and the matrix have limited their applications. Therefore, many methods have been proposed for the preparation of metallic or non-metallic coated fiber tow to prevent the chemical reaction [5-9]. The reaction at the carbon-aluminum interface at high temperatures to form aluminum carbide has long been considered to affect critically the strength of C/Al composites [10, 11]. The formation of aluminum carbide at the fiber-matrix interface was considered to induce poor composite properties, as observed by Pepper and Pent [12], Xiangun and Hanlin[13].

A very thin and uniform coating over a fiber surface can promote the characteristics of carbon fiber composites; therefore, many methods have been proposed for the preparation of metallic deposition to improve and enhance the surface state of carbon fibers. However, the variation in the thickness of the coating on a carbon fiber tow has been observed. The variation between fibers on the inside of each bundle and those on the outside, however, is up to 20% ~ 90% [15, 16, 17-22]. The thickness of the layer on the monofilaments in the center of the fiber tow is considerably less than that of the layer deposited on the monofilaments at the outer of the tow. The results demonstrate that the EMI shielding capability of the fibers decreased as the coating thickness reduced, but the strength of the fibers decreased with increasing coating thickness [14, 16, 23-26]. Therefore, significant difference of the mechanical behaviors and the physical properties yielded between the inner and outer fibers of a tow. The non-uniform activation is caused by the contact of carbon fiber. Bobka et al. [27, 28, 29] reported that oxidation treatment led to a non-uniform etching of the fibers when carbon fiber tows were treated by oxygen to modify the surface of the filaments. Therefore, the outer filaments are strongly attacked while those in the interior of the bundle are hardly attacked.

The excess of compact carbon filaments is responsible for the non-uniform activation and the non-uniformity of the subsequent coating in a carbon fiber tow [21, 22]. It may not be possible to get an identical thin film and coat less than 0.2 μm thin layer on each fiber in a carbon fiber tow [15, 18, 30-31]. The change in the film thickness is as a function of the distance from the axis of the fiber tow and as the relative concentration of the chemicals as a function of the difference from the axis of the fiber tow for different positions in the reactor and for different deposition conditions. Deposition onto the central fibers is difficult; reactants are prevented from approaching the inner fibers. Thus, if the fibers are separated uniformly, it is advantageous for the improvement of fiber coatings [25, 32, 33].

Processes and apparatus were developed for pneumatically spreading graphite or other carbon filaments from a tow bundle to form a sheet or a ribbon in which the filaments were maintained in parallel [34-39]. The developmental history of the pneumatic spreading system was listed in Table I, and the schematic diagrams of the spreading system were presented in Fig. 1-1~ Fig 1-6. The spread filaments can be bonded together in the form of a tape impregnated any of the well-known resins or thermoplastic polymers which can be cured or molded under heat and pressure. The key component in the pneumatic spreading system is the spreader. The carbon fiber tow is comprised of thousands of filaments and the carbon filaments are interacted with air in the spreader.

Baucom and Marchello were the first to attempt to design a pneumatic spreader [40]. They modeled a single fiber suspended in air under both a pressure drop and tow tension, and derived a formulation from orifice equation to predict the spread angle of a carbon fiber tow in the spreader. Comparisons of the experimental data for a 12k tow (containing 12,000 filaments) with the single fiber prediction indicated that the results were not satisfactory because there is a large deviation in the spread degree between the experiment and the model. They concluded the flow-field is too complex in the spreader to know the interaction between the airflow and fibers, for the model derived from Bernoullis' ideal assumptions can not calculate and present the overall status of airflow. Also, the model of the single fiber prediction can not describe the internal flow-field of the spreader. Newell and Kawabe et al. focused their research on the design and processing factors of an effective pneumatic spreading system, respectively [41, 42]. They qualitatively examined the spreading characteristics of the carbon fiber tow in the spreader under various conditions; however, the discussion of the interaction between the flow fluid and the carbon fiber tow was unclear and incomplete because the flow field in the spreader remained unknown. Klettet al. employed a pressurized air-comb to separate the tow bundle before a coating process [34]. Also, they qualitatively illuminated the uniform spreading of a fiber tow exposed individual filaments by the air-comb for subsequent coating, but neither the procedures of tow spreading in the air-comb nor the spreading degree of the fiber tow were discussed. Accordingly, the spreading degree for a carbon fiber tow was considered in a very limited sense in the cited works, only a few which considered the evenness of a spread tow. When the fiber tow cannot be uniformly spread, some of the fibers pile up tightly. Without effective spreading, the effects of fiber bridging may become severe [42].

The critical part of the spreading process is the design of the fiber spreader itself. None of the cited investigations explored the effect of the airflow by the spreader design, and none of them qualitatively and quantitatively analyzed the internal flow patterns of the fiber spreader in detail. A highly chaotic or turbulent flow field would bring about the variation in air velocity and airflow agitation in the spreader. Agitation can entangle fibers, making fiber spreading difficult and damaging the fibers. The characteristics of the internal flow field in the pneumatic spreader will be given by the design. This present work aims to establish a three-dimensional (3-D) model of the spreader by applying a computational fluid dynamics (CFD) method combined with far field treatment to study the internal flow field of the spreader. The CFD method was also implemented to visualize velocity fields, pressure and streamlines distribution, and thus elucidates the spreading mechanism of the new design spreader to optimize the design factors. The fiber pneumatic spreader is used to estimate experimentally the effect of air velocity on a carbon fiber tow. The goal is to develop an effective pneumatic fiber spreading system that can uniformly spread the fiber tow for post treatment, such as surface treatment or surface coating, and investigate the nucleation and growth of EN deposit in a spread and unspread carbon fiber tow, and we will exam the controlled mechanism that causes the non-uniform Ni coating by the spread carbon fiber tow. Finally, a method will be provided to obtain the thin and uniform Ni coating on a carbon fiber tow.

## Ⅱ. References


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Table I

***Developmental history of the pneumatic spreading system***

***1972 John N. Hall et al., USA.***

***1975 Clare G. Daniels, USA.***

***1989 Paul E. McMahon et al.,USA.***

***1990 M. Baucom et al.,USA.***

***1997 Kazumasa Kawabe et al., Jap.***

***1999 James A Newell et al., UK.***

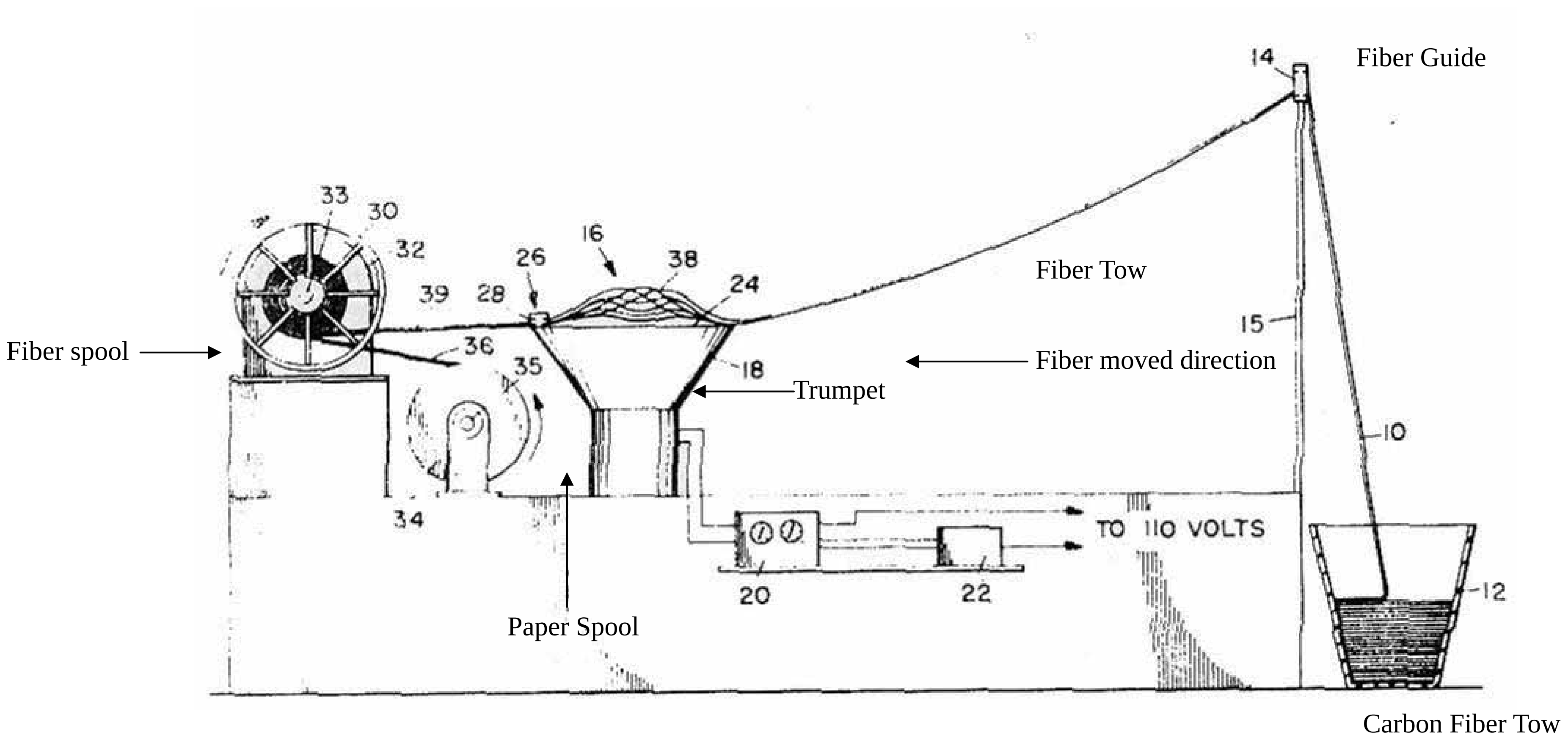



Fig. 1-1 A Schematic diagram of the carbon fiber tow spreading system by sound vibration.

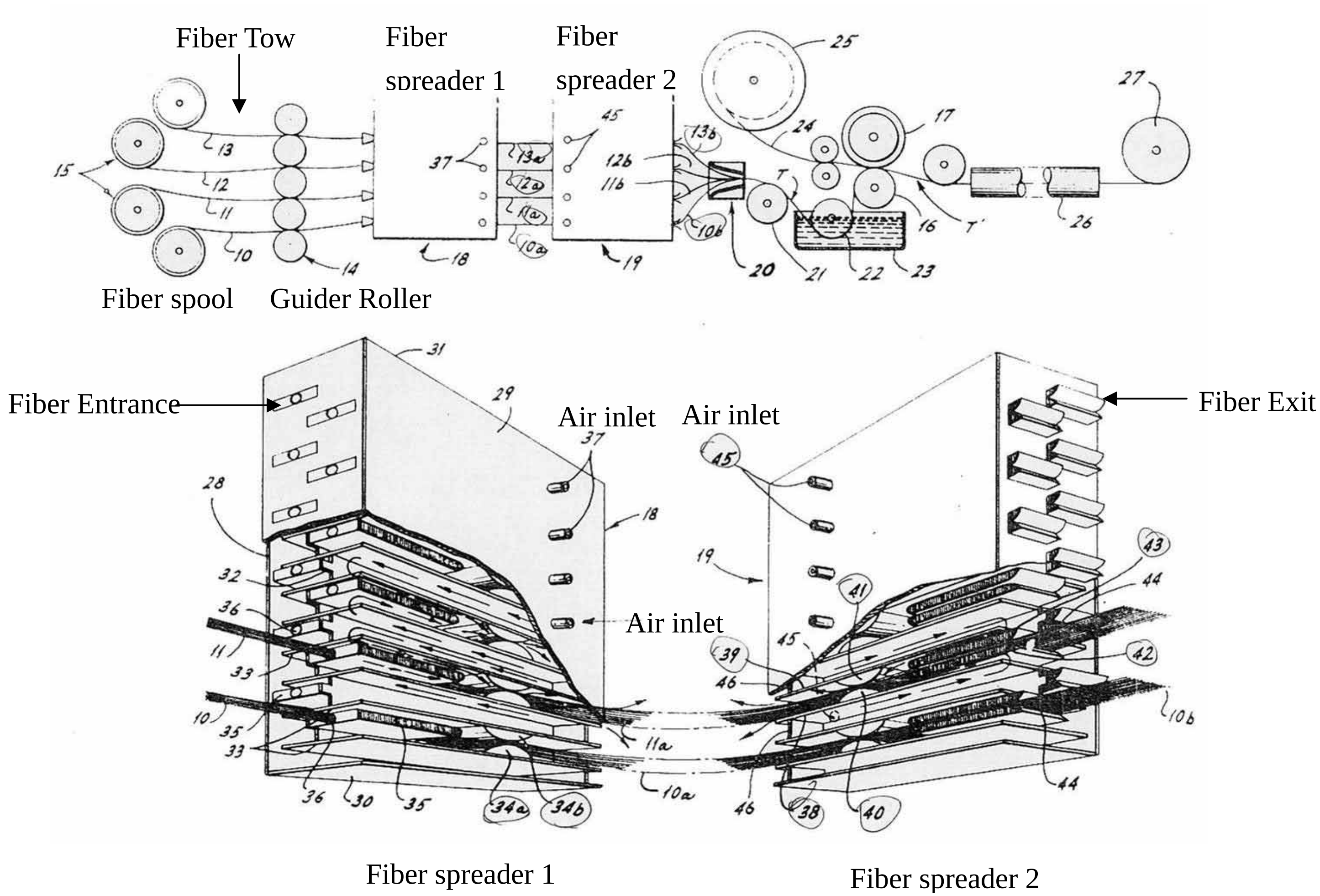



Fig. 1-2 A carbon fiber tow pneumatic spreading system and the fiber pneumatic spreader.

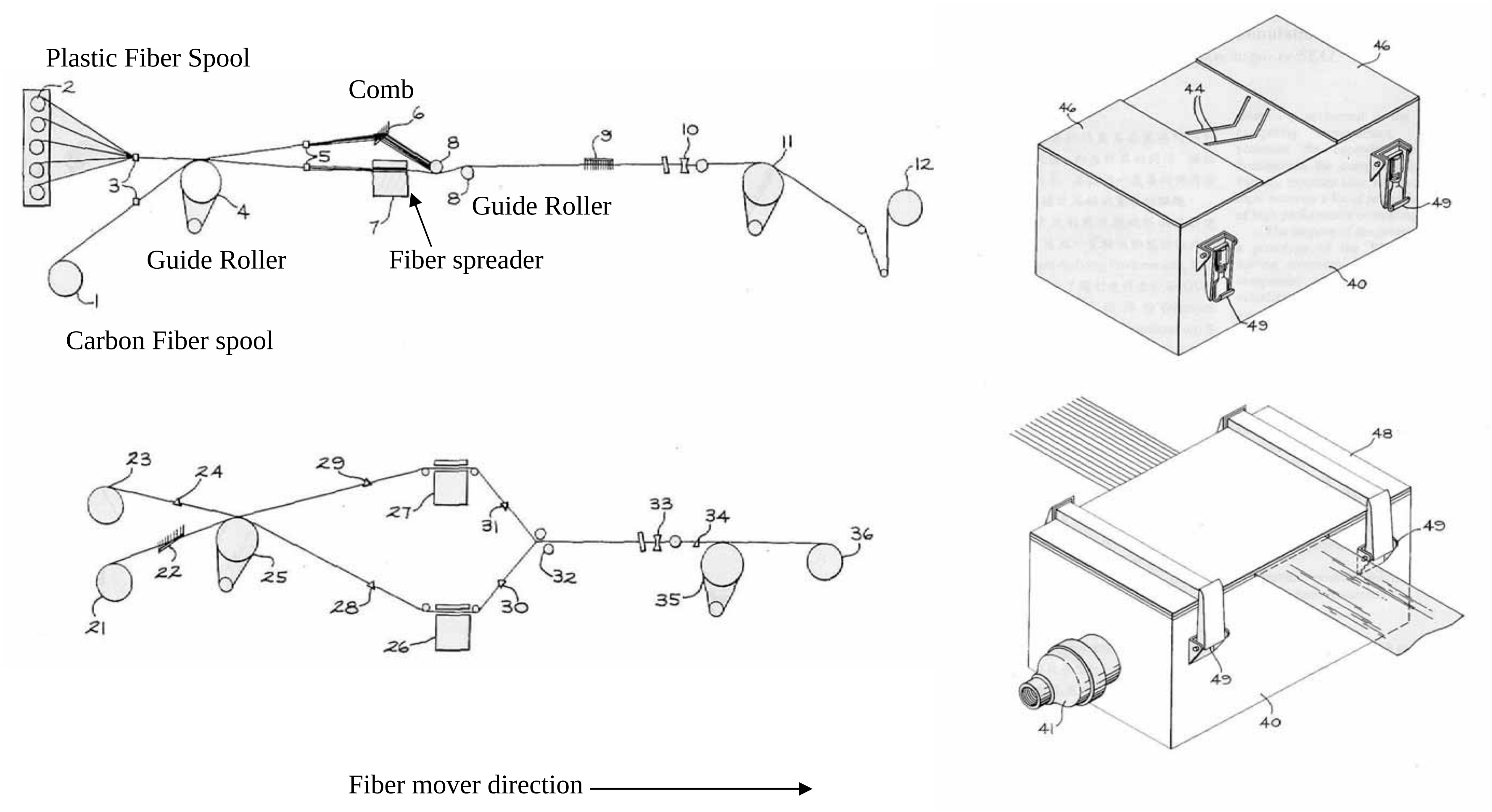
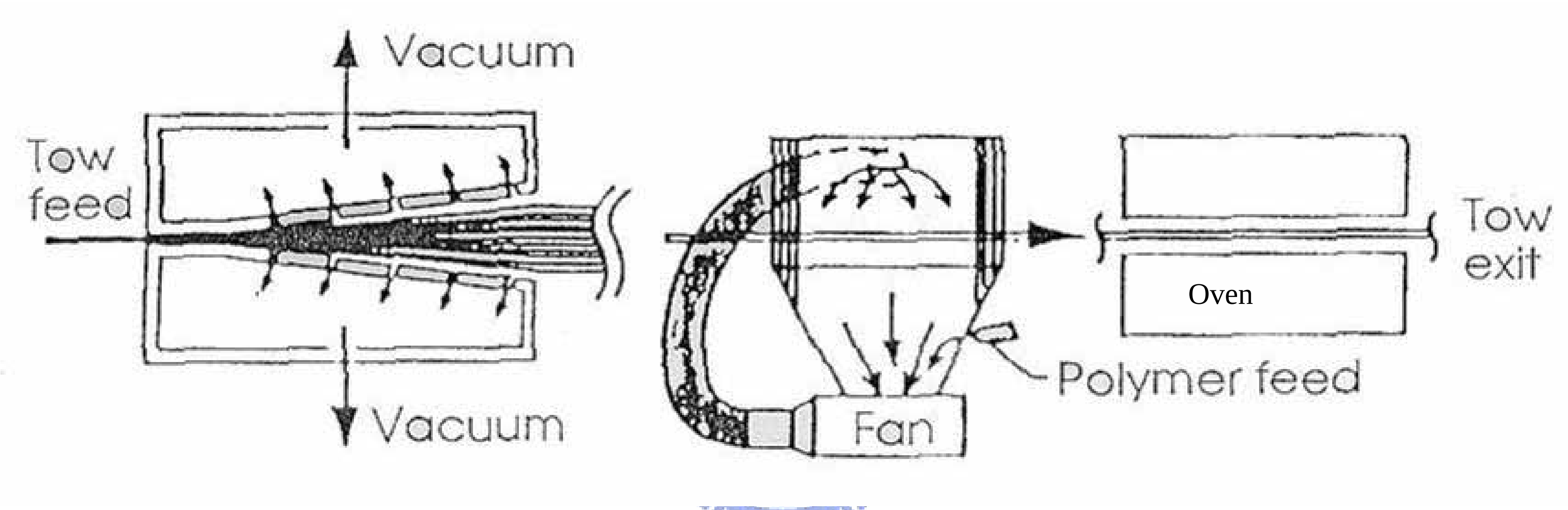



Fig. 1-3 A carbon fiber tow pneumatic spreading system and the pneumatic spreader.




Fiber spreader

Fig. 1-4 A carbon fiber tow pneumatic spreading system and the vacuum spreader for making pre-preg.

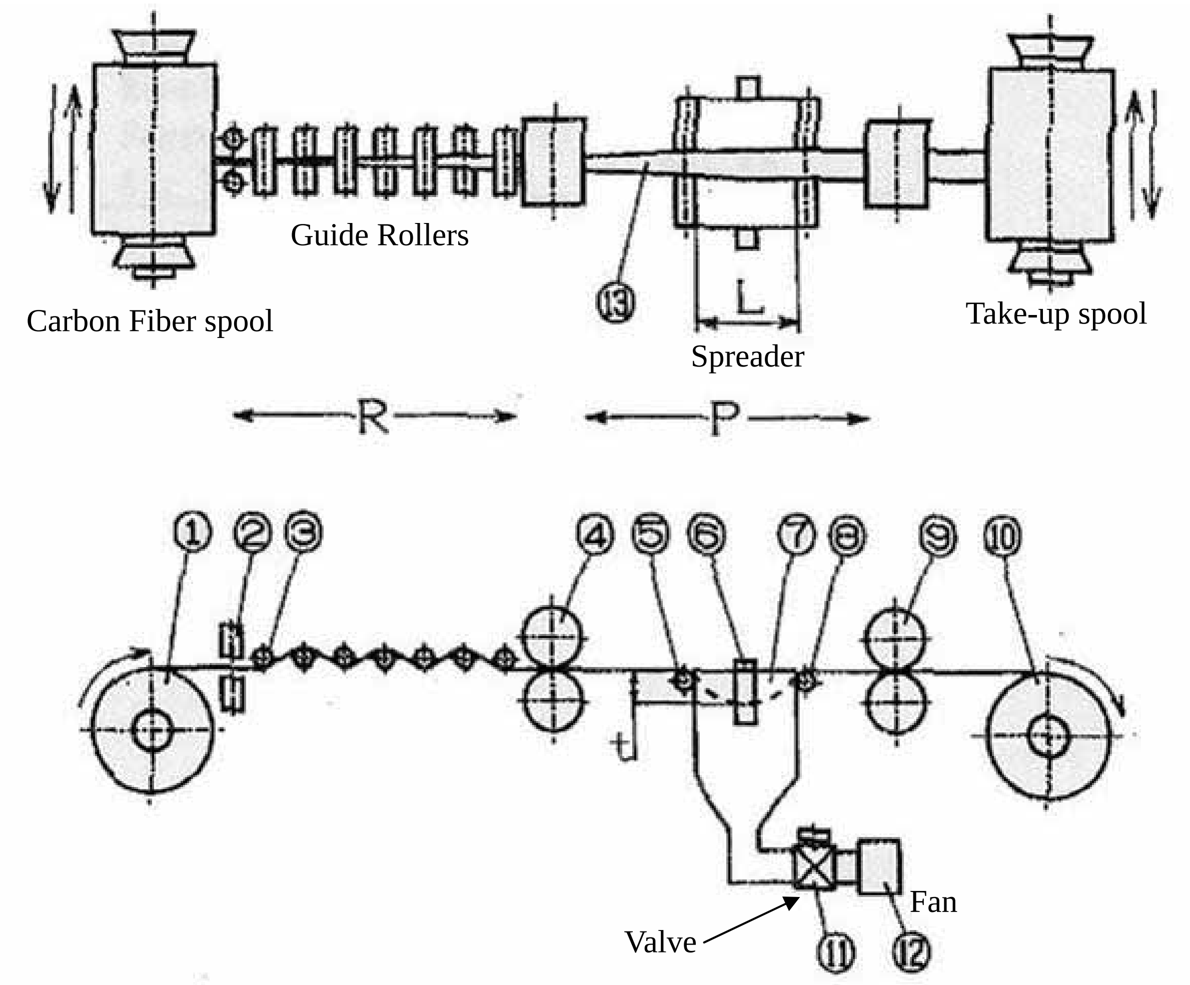



Fig. 1-5 A carbon fiber tow pneumatic spreading system and the spreading procedures.

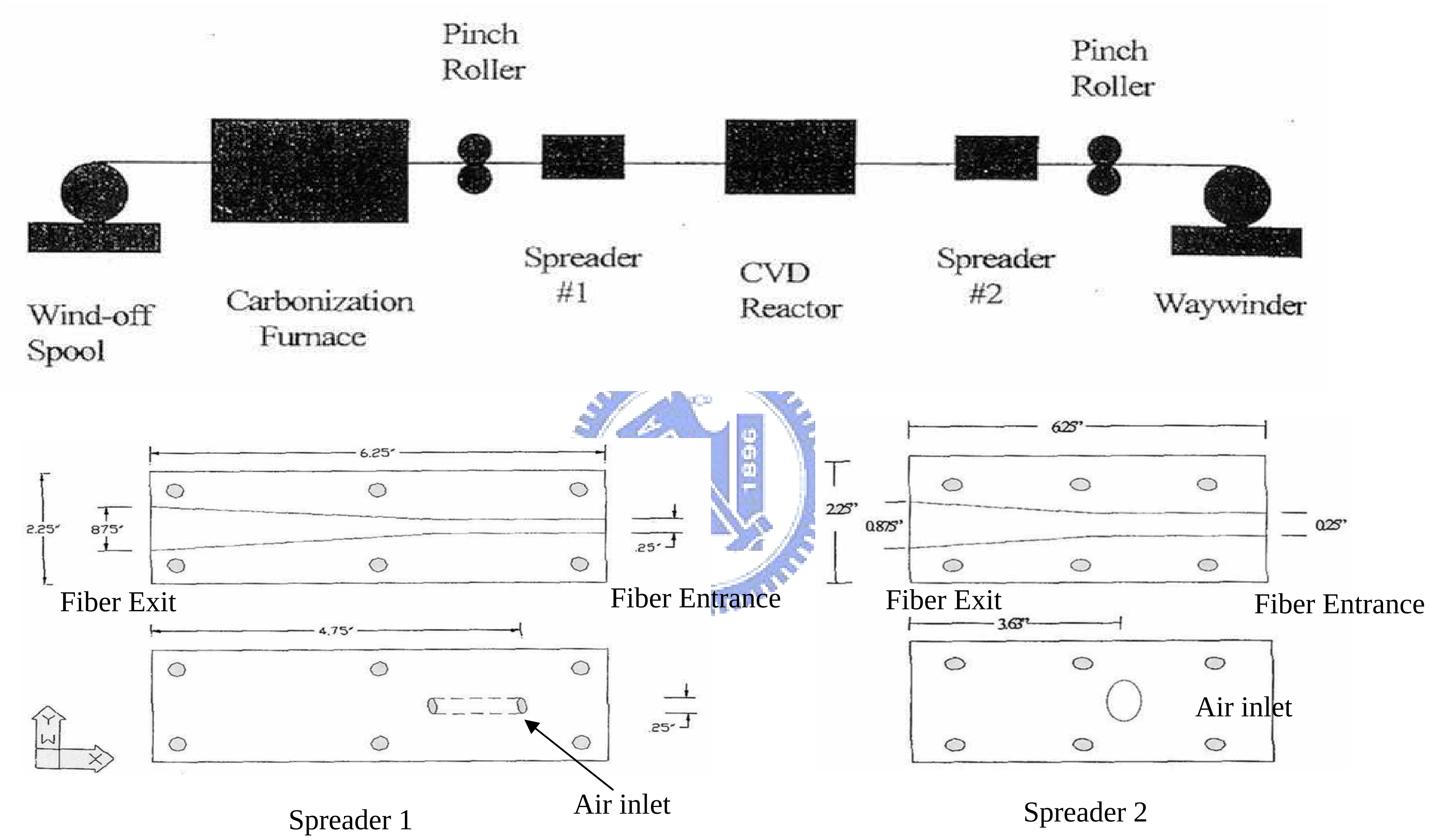



Fig. 1-6 A schematic diagram of the fiber tow pneumatic spreading system and the pneumatic spreaders for making carbon fiber.