Multi-ply sheet formation on inclined-wire formers

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The inclined-wire former is designed to produce a uniform sheet from low-consistency furnishes.

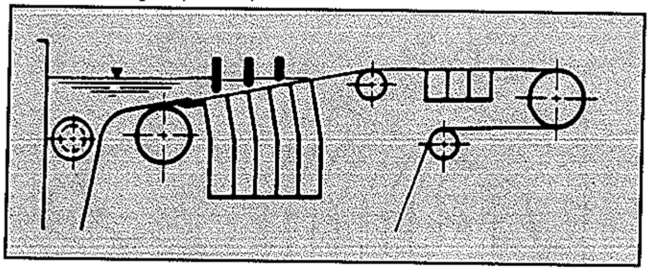
Slurries containing long fibers (3-25 mm) require high dilutions (low consistencies of 0.02%-0.065%) to obtain good dispersion and good sheet formation. Long fibers need sufficient space to remain separated and prevent entanglement. If the fibers are also thin (i.e., high length-to-diameter ratio), their lack of stiffness will also promote entanglement. Limp fibers tend to entangle when they collide, while stiff fibers tend to rebound.

High-dilution slurries create large volumes of water at given line speeds. The resulting slice opening on the wire would produce a wall of forming water between 40 mm and 150 mm deep, which would be difficult to control on a fourdrinier table. To effectively control this river of water, a pond is required with sides and other restrictions. The inclined-wire former was developed to cope with this problem. The sheet structures of products made from low-consistency slurries on inclined-wire formers are usually extremely uniform and well formed.

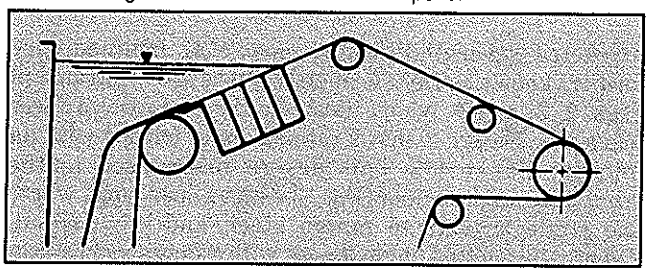
In addition to the control of the pond sides, the divided suction forming box of an inclined-wire former allows the stock's drainage rate to be controlled in a progressive manner along the forming zone. Drainage is retarded initially, and vacuum is applied as required when the formed sheet retards the drainage naturally.

In the fully developed designs, the top of the pond is also restricted to control the flow velocity of the stock through the entire length of the forming zone. This is done with a flow synchronizer.

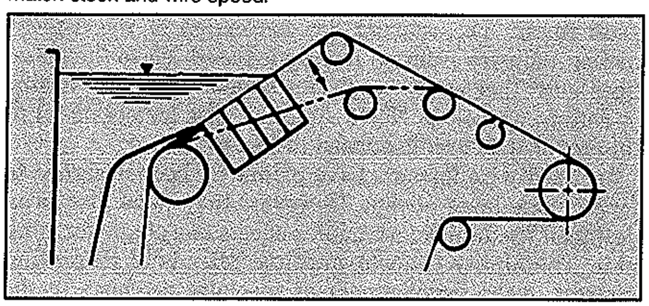
1. The early inclined-wire formers were little more than a fourdrinier table with a slight uphill slope.



2. Fixed-angle former with an uncontrolled pond.



3. Adjustable-angle former with an open pond. The angle adjusts to match stock and wire speed.



Development of the inclined-wire former

The first inclined-wire formers developed in the 1930s were little more than a fourdrinier table with a slight uphill slope. This design is illustrated in **Fig. 1**. These machines ran at low speeds. The hydraulic capacity of these units was not much greater than that of a standard fourdrinier headbox. Stock velocity was controlled through the use of multiple slices, as seen in Fig. 1.

The modern inclined-wire former was initially developed to accommodate slurries containing hemp and rayon fibers. These are both free draining and require low headbox consistencies. Hemp is the primary raw material for tea bags, and the first inclined wires were used for the manufacture of tea bag stock.

As more types of synthetic fibers became available and the nonwoven industry developed, the number of low-consistency forming applications increased. Our company

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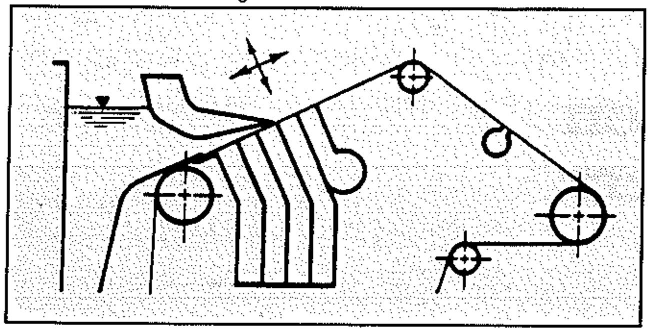
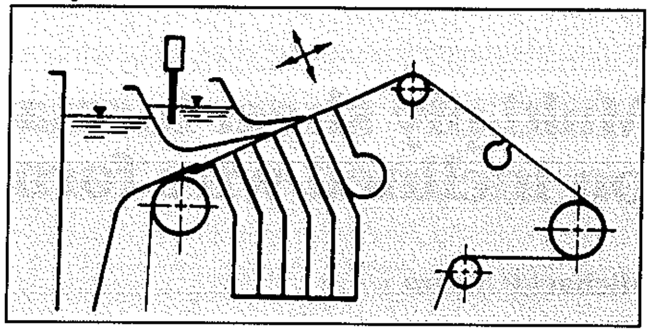
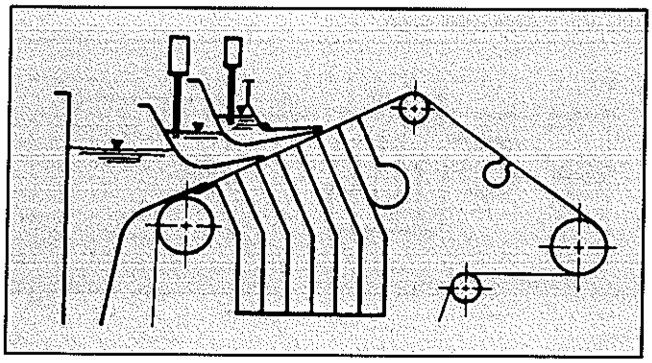
4. Fixed-angle former with a flow synchronizer to control the speed of the stock in the forming zone.



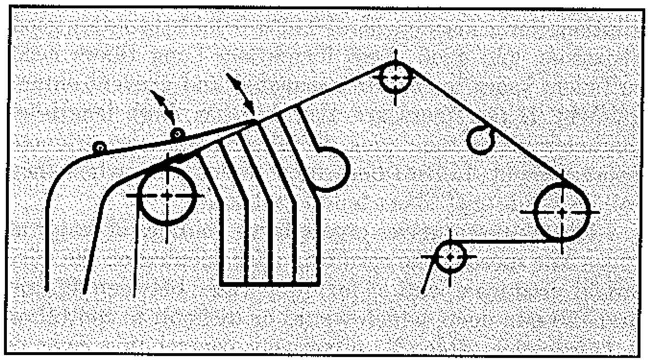
5. Inclined-wire former for manufacture of two-ply sheets in a single forming unit.



6. Inclined-wire former for manufacture of three-ply sheets in a single forming unit.



7. Inclined-wire former with hydraulic headbox.



marketed several different models of inclined-wire formers known as Deltaformers®. These are illustrated in **Figs. 2, 3,** and **4**, which illustrate the evolution of these machines. Figure 2 shows a fixed-angle former with an uncontrolled pond. This design progressed to the adjustable-angle former (Fig. 3) with an open pond, where the angle adjusts to match stock and wire speed. Eventually, a fixed-angle design with a flow synchronizer was developed (Fig. 4). The flow synchronizer controlled the speed of the stock in the forming zone.

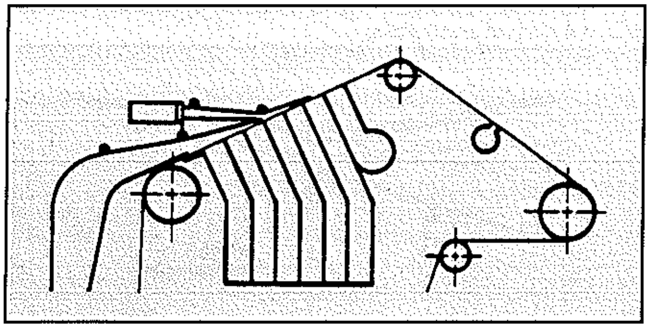
In 1968, we designed and manufactured the first inclined-wire former exclusively for the manufacture of a sheet from glass fibers. This started the conversion of the asphalt roofing industry from an inorganic-based felt to the glass-fiber mats that have become the standard of the industry in Europe as well as North America. The formers used in this application are illustrated in Fig. 4.

Inclined-wire formers have primarily been designed to form single-layer sheets. However, they have also been designed for duplex and triplex sheets in a single forming unit. The ability to form multiple plies is of increasing interest in the development of specialty products in the filtration industry and also in the manufacture of durable nonwovens and composite structures. Advanced technologies use a combination of synthetic fibers and thermoplastic resins. A scrim reinforcement frequently is used as a carrier material either on one surface or in the middle of the composite sheet. **Figures 5** and **6** illustrate these multi-ply designs.

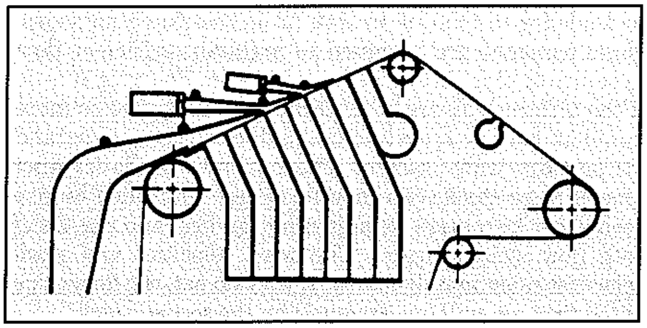
The hydraulic headbox was applied to the inclined-wire former to increase line speeds and improve sheet formation. This configuration is illustrated in **Fig.** 7. A two-ply version of the hydraulic headbox inclined-wire former, the Duomat®, is illustrated in **Fig. 8**, and a three-ply version is illustrated in **Fig. 9**. The inclined-wire former shown in **Fig. 10** illustrates another variation that can be used to produce a two-ply sheet, with a scrim or other layer introduced between the two plies being formed by the primary headbox. An auxiliary or secondary headbox is located on a flat or slightly inclined section of the extended wire from the former.

The former illustrated in Fig. 9 has not yet been produced commercially. Laboratory trials and investigations into potential uses indicate that the composite sheets produced on a machine like this would most likely consist of a heavy center ply with two thinner outside plies. The outer plies would have special properties. Such a sheet could be produced using the former illustrated in Fig. 10, in conjunction with a Harper fourdrinier-type reversing wire and an auxiliary headbox to apply the third layer onto the bottom of the sheet. An alternative to this would be a Duomat® with the primary or first-ply headbox having a low hydraulic capacity; the (second-ply) secondary headbox having a much larger hydraulic headbox; and the third ply applied on the extended wire, using an auxiliary headbox in conjunction with a top-wire dewatering device.

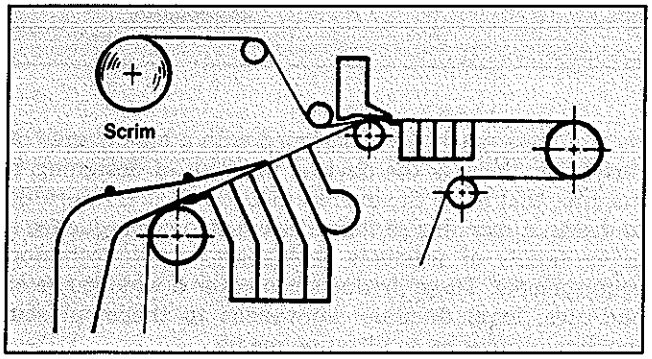
8. Inclined-wire former with hydraulic headbox—two-ply version.



9. Inclined-wire former with hydraulic headbox—three-ply version.



10. Inclined-wire former for production of two-ply sheets with a scrim layer between the two plies. The first ply is formed by the primary headbox. The other ply is formed by a secondary headbox located on a flat extension.



Composites

Composite sheets are formed of multiple materials. Each of these materials contributes some beneficial property to the final sheet. In some cases, synergistic effects are obtained. The three primary types of composites are:

1. Homogeneous blends of fibers and materials. Blends are engineered to provide specific benefits. For example, a manufacturer who wanted to produce a strong sheet that is also stretchable and conformable could blend in glass fibers for strength and polyester fibers for elasticity.
2. Layered blends for filtration applications. For example, an open, porous sheet on one side, progressing to a closed nonporous sheet on the other side, would provide progressive filtration and extend filter life.
3. Layered blends for specific surface properties. This type of application might include a strong core with a smooth, printable surface on one side and a water-repellent surface on the other side.

The possibilities for composite structures are numerous, with both technical and economic objectives. The technical objective focuses on the composite's surface properties. The economic objective is to obtain the desired surface properties at the lowest cost. This is done by using an inexpensive stock for bulk and/or strength in the core of the sheet.

There are various ways of producing composites, including:

- Multicylinder machine that uses different stocks in the various cylinder molds and then couches them into a layered product.
- Fourdrinier with primary and secondary headboxes.
- Three-layer boxes that use one stock on the top, one stock on the bottom, and a third stock in the center of the sheet.
- Inverformers® and making rolls.
- Rotoformers® with two- and three-stock headboxes.
- Inclined-wire formers with two- and three-stock headboxes (Figs. 5 and 6).

In some composite sheets, various scrims are included for additional unidirectional reinforcement. Other composites include a continuous fiber scrim or a sheet of some sort to provide multidirectional reinforcement. Yet other composite sheets contain various powders or resins for use in other processes, such as pultrusion or matched-metal die molding.

Multi-ply inclined-wire formers

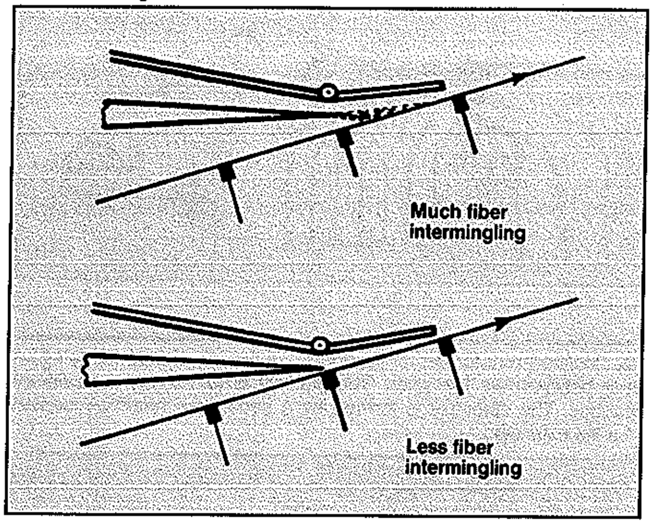
The Duomat Deltaformer®, a multi-ply inclined-wire former, was a development resulting from a desire to produce special sheets using fibers requiring high dilutions and having free-draining stocks. The hydraulic headbox was adapted to the inclined-wire former in an effort to increase control of sheet structure and uniformity at higher production speeds. The multi-ply capability was a natural extension of this development.

This machine can provide a three-layer sheet from two stocks. It does this by forming a center layer that is a mixture of the two stocks. A major advantage of the dual-headbox design (as opposed to using separate forming units) is that the ply bond between the two layers is much improved and, in fact, can be controlled to the degree desired. This is particularly useful when two stocks are being mixed to form a progressively dense structure, such as a filter. With a rapidly draining open stock on the bottom and a much more closed and slower-draining sheet on the top, an inner layer made up of the two fiber types can be formed. The properties of this inner layer are controlled by adjusting the heel and toe settings in the headbox. The process is illustrated in **Fig. 11**.

The hydraulic headbox allows low- and high-density fibers to be run simultaneously because the fibers have no tendency to float or to sink in its restricted passages. These passages are designed to maintain sufficient flow velocities to keep the stocks in suspension. The weight ratio of the different layers is controlled by using two or more complete stock systems (including thick stock systems) and the primary water system. The velocities in the forming zone of these stocks can then be closely controlled to give good sheet formation by adjusting the heel and the toe of both flow synchronizers. The wire velocities and stock velocities must match closely. If they do not, the formation of the first ply will be disrupted by the second stock.

A dual-headbox system can also be used to improve formation of difficult-to-form stocks, such as mercerized pulp. A high degree of sheet uniformity can be obtained by running the same stock through two headboxes. Trials show that the uniformity of a dual-layer sheet formed on a two-ply former is superior to that of a sheet formed on a single-ply former running the same stock, at the same forming length, at the same speed, and at the same headbox consistency.

11. The multi-ply inclined-wire former can make a three-layer sheet from two different stocks by forming a center layer that is a mixture of the two stocks. The middle layer is controlled by adjusting the heel and toe settings in the headbox.



Conclusion

The manufacturer of composite structures can choose from a wide range of multi-ply inclined-wire formers. While each of these machines is designed with a high degree of flexibility, there is the obvious problem of designing a machine that is too flexible. In most cases, it is desirable to design a machine so that it is capable of producing a given family of products that share certain common requirements. These products can cover a wide range of end-uses, from durable nonwovens to thermoplastic molding composites to filtration media.

The formers of the future are being developed today; however, the development of the composite sheets and materials is just beginning.

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