

Engineered structures for use in disposable incontinence products

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Abstract: The background and evolution of absorbent disposable hygiene products is discussed. The current technology used to produce disposable hygiene products such as baby diapers, feminine hygiene products and adult incontinence management products is shown to have a number of manufacturing and in-use problems. Alternative technologies, such as multilayer composite webs offer the opportunity to achieve better product weight control, and therefore better control over the other related properties, reduced raw material waste and improved functional characteristics. There are still problems to be resolved when using such composite materials, but the potential of these new technologies has now been established.

Keywords: incontinence management, disposable, absorbent products, multilayer, composites

1 INTRODUCTION

The disposable absorbent hygiene products business sector covers products for baby care, feminine hygiene and adult incontinence management. The evolution and development of these three main groups of hygiene products have followed related but different timetables to arrive at the products that are available today. These products are all linked by the same basic requirement that they have to first and foremost be absorbent structures; however, they differ from each other because of the differences in the volumes and characteristics of the fluids that they are required to absorb.

Absorbency, in this context, may be described as an interdisciplinary scientific phenomenon that deals with the absorption of aqueous-like fluids by porous media, or more specifically by fibrous systems. In an ideal forming process, the cellulose fibres that normally comprise the major portion of the absorbent core of these products, would be laid down from the air stream as individual fibres in order to avoid the creation of fibre aggregates. In the current processes, where the pads are formed individually, this is not possible, as there is very little time to adjust the fibre distribution before pad formation. As a result there is a relatively high variation in the pad weight and therefore in other pad-weight-related properties. This weight variation problem is illustrated in Fig. 1 which shows the pad weight variation within

one pack of adult incontinence pads and for products of various sizes. It can be seen that the problem exists across the whole range.

2 INCONTINENCE PRODUCTS—EVOLUTIONARY TIMEFRAME

It would be reasonable to claim that the early work on underpads was contributory to the formulation of a strategy with respect to adult incontinence products as well as baby diapers. Two events are worthy of note:

1. 1936: absorbent underpad based on unbleached creped tissue.
2. 1950: Johnson and Johnson (USA) introduced a rectangular underpad of cellulose wadding with a wet strength tissue coverstock and a plastic backing.

It was 1972 before the first disposable absorbent products specifically designed for incontinence management appeared. It is necessary, because of the widely differing functional requirements to distinguish between products designed for the management of heavy and/or double incontinence and those aimed at supplying a management option for light incontinence sufferers (see Table 1).

In the absorbent products business there has been a degree of cross-fertilization between the product developments. Disposable baby diapers appeared as a two-piece or insert system around 1940, but it was not until the appearance of the all-in-one type that the market for these products really gathered momentum. The

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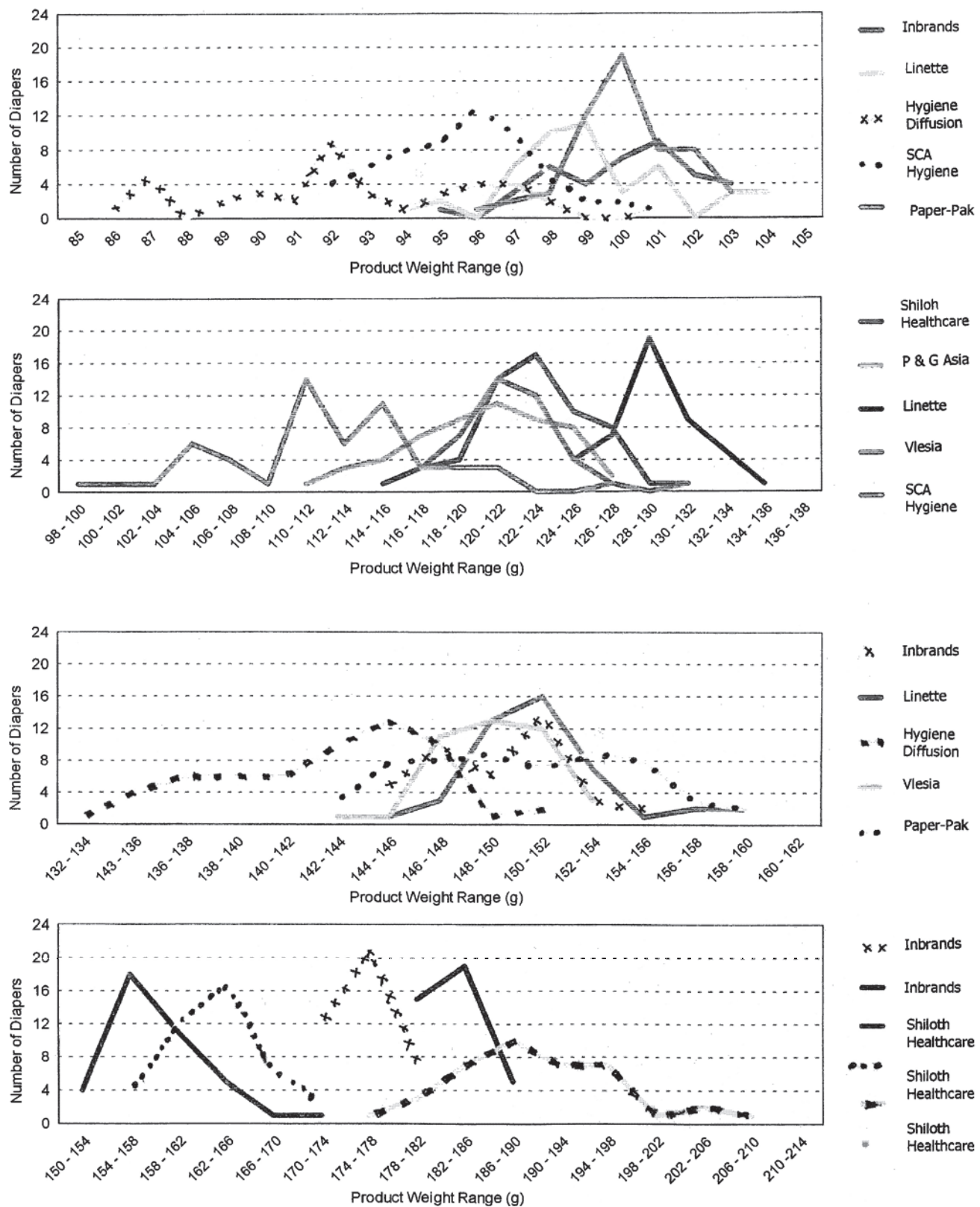


Fig. 1 Pad weight variation of adult incontinence products produced by current 'assembly-line' production (courtesy BASF Technical Services)

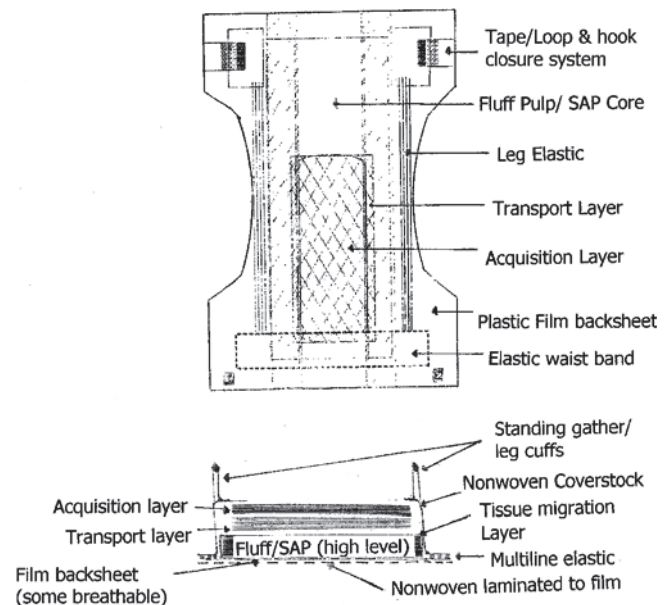
Table 1 Product design evaluation

Date	Location	Product
Heavy incontinence management		
1972	Europe	Rectangular fluff pulp pad with plastic liner; two-piece system
1978	USA	Procter and Gamble introduce first all-in-one product for adults
1987	Japan	Pad and pant system introduced
	Europe	Superabsorbent polymer introduced into two-piece system
1992	Europe	All-in-one product with acquisition/distribution layer
1993	Europe	Use of modified ('curly') cellulose fibres as an acquisition layer
1995	Europe	Waist elastics introduced
1995	Japan	First adult pant diaper
1998	Europe	First adult training pant
	USA	
2000	Europe	All-in-one system with adjustable waist belt fixing system
	USA	
Light incontinence management		
1983	Europe	First product specifically designed for management of light incontinence
1985	USA	Product produced from 100 per cent synthetic materials with polyester wadding, superabsorbent polymer and a foam 'container' structure
Mid-1980s	Europe	Thermobonded airlaid pad
1989	Europe	Dual core structure
1994	Europe	Fast-action acquisition layer introduced
1998	Europe	Odour control with acidic superabsorbers
1998	USA	Pant-type product for light incontinence
2000	Europe	Panty liner sized pad for light incontinence
2000	USA	New design of male products based on airlaid materials

significance of this in terms of adult incontinence products is that when the first specifically designed products for the management of adult incontinence appeared in 1972, they drew heavily on the development work that had gone into the two baby care products. It was not therefore suprising that the first adult all-in-one body-worn diapers were based on a similar design to those for babies but several sizes larger.

In the case of developments in the feminine hygiene field, the developments are not so directly transferable because of the difference in both the characteristics and volume of the fluid to be absorbed, but they became important in a different way. Feminine hygiene product manufacturers have tended to be more innovative in the way in which they have approached not only the functional requirements of their products in terms of absorbency, but also in other secondary areas such as product comfort in use, odour control systems and skin care treatments.

There would appear to have been a reluctance on the part of adult incontinence product producers to look at the developments that have taken place in the sanitary napkin/panty shield sector as being equally relevant to their products. It is only within the past year that thin, discrete products, based on sanitary napkin technology, have been introduced for the management of light incontinence. Part of the problem comes from the limitations of the current 'assembly-line' manufacturing technology used for adult products. Feminine hygiene products have adopted pre-formed core structures for many of their products and have moved on to some of the more complex pre-formed materials that are now available. The structure of a modern version of a baby diaper is shown

**Fig. 2** Structure of modern baby diaper

in Fig. 2. This type of product is currently produced by an assembly-line process, whereby the raw materials and pre-formed component webs such as the topsheet and backsheet film, are selected and brought together within the diaper machine. This machine combines the materials together to produce finished units basically one unit at a time, albeit at relatively high speed. The production of all-in-one-type adult products is handled in the same way, but at a lower throughput rate.

3 CURRENT PRODUCT PERFORMANCE REQUIREMENTS

3.1 Functional requirements

Most of the products currently available are produced by creating a number of layers within the overall structure in an attempt to achieve better fluid management. Absorbent hygiene products have to fulfil a number of functions in order to be satisfactory in use, among these requirements are the following:

1. To keep the surface layer as dry as possible in order to facilitate good skin care conditions.
2. To transfer fluids from the surface through to an effective storage layer.
3. To absorb and store transmitted fluids in such a way that they will not be released back through the structure to the surface.
4. To provide an efficient containment system to contain the absorbent layers in order to protect the user's environment.
5. To be capable of appropriate and environmentally compatible disposal after use.

3.2 Structure of current products

Presently available products attempt to meet these potentially incompatible requirements by using a variety of different materials, some in the form of pre-formed webs, to create a series of functional layers within the structure (Fig. 2). The problems associated with the assembly-line system are that, despite some very skilled engineering solutions from the machinery builders, the system is not capable of very precise control at the operating speeds needed to produce 3–400 adult products per minute; commercial pressures are pushing this forward to 5–600 units per minute. Consequently the system design tends to overengineer the product to ensure that they can meet most, if not all, of the functional requirements.

In addition, the current products designated for adult incontinence use are based on the design and manufacturing technology of baby diapers, in the case of products for the management of heavy or double incontinence, while feminine hygiene developments are used in the case of light incontinence products. In both cases, it is important to remember that the adult products have to be able to deal with larger volumes of liquid and yet handle them in an effective way and this requirement brings with it additional problems.

3.3 Production line requirements

Figure 3 illustrates the type of machine used for the production of adult products for the management of light urinary incontinence. Adult incontinence products pro-

duced by this assembly-line system can fulfil the basic functions required by these products. They achieve this by manufacturing products that are physically large and overengineered and which rely on a relatively large bulk of absorbent material, normally fluff cellulose pulp combined with superabsorbent polymers, to provide the absorption. Unfortunately this system does not necessarily ensure good liquid transport properties within the pad or do very much for the aesthetics and comfort factors required of these products. The problems are further complicated by the use, by some sufferers, of feminine hygiene or baby care products in an attempt to 'manage' their incontinence, and the subsequent unsatisfactory performance of such products that were designed to handle different fluid volumes and viscosities. While this type of misuse problem is serious, there are also a number of more fundamental problems associated with the type of product produced by this manufacturing technique.

The current products are composites consisting of a number of different structural elements put together in a designed way in an attempt to provide a structure that will meet all of the functional requirements. These building blocks are made up of:

- (a) a top sheet layer which can be a pre-formed non-woven carded fibre web, a continuous filament web or a plastic film with carefully designed holes;
- (b) an acquisition and transport layer, which may be non-woven, made of synthetic fibres or a modified cellulose fibre layer;
- (c) a wetlaid tissue wrap layer that surrounds the core;
- (d) a storage core layer that is made up of cellulose fluff pulp and superabsorbent polymers;
- (e) a backing containment layer that is normally a plastic film, which may be breathable. It may also be covered with another layer of non-woven material to give a cloth-like feel to the external surface.

These components are assembled by the machine and held in their relative positions within the structure by the use of hot-melt adhesives. With the exception of the hot-melt adhesives, the other components are all concerned with the containment or control of the fluid within the structure. The fact that the individual components are produced off-line and then assembled on a dedicated manufacturing unit produces a second potential area of difficulty in addition to the product weight variation. Each web of component material has to be capable of being fed through the production unit at relatively high speed (3–400 units per minute) and this requires these webs to have sufficient strength and elongation properties to run continuously without breaks. This requirement limits the extent to which the web may be modified for purely absorbency characteristics, for example, weight reduction. Further problems arise because, while there is some understanding about the interaction of fluids within each component (this can be

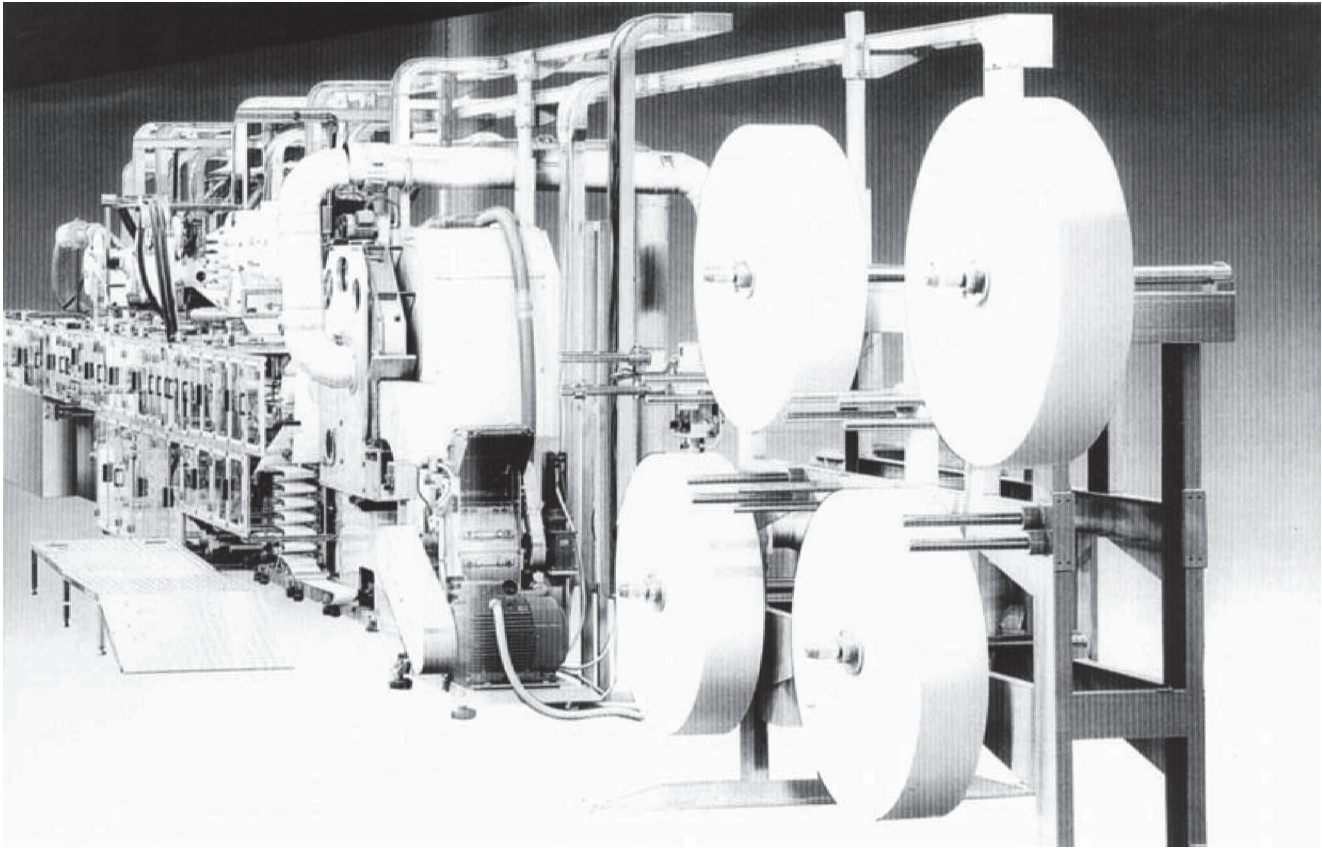


Fig. 3 Production machine for light incontinence products

defined to some extent by the standard absorbency models), very little is known about the flow through the interfaces that exist between the different components. Any attempt to produce significantly better products needs to address these problems.

4 ALTERNATIVE TECHNOLOGIES

In the past 3 years there has been a major effort to develop an alternative method of manufacture of absorbent products in order to be able to produce more precisely controlled structures. The current method of forming absorbent products disperses the fluff pulp fibres by dry defibration of the cellulose and dispersion of these fibres in air. These dispersed airborne fibres are then condensed into individual absorbent pads on a device known as a drum former (Fig. 4) which is normally an integral part of a machine such as that shown in Fig. 3.

The concept of using air as a medium for dispersing cellulose fibres owes its origin to work that was originally aimed at the production of paper grades without the use of water as the fibre dispersing medium [1, 2]. This development did not prove commercially attractive, but it did give rise to further work using air as the transport medium. While the existing absorbent pad technology uses air dispersion on a small scale (to form individual

pads), the other 'paper' development work was evaluating the concept of producing wide continuous rolls of air-formed material. While this proved unsatisfactory from a paper product viewpoint, it did produce some low-density latex bonded products that were found suitable for tablecloths and table napkins for example.

Development of the technique was moved significantly forward by the work of Karl Kroyer, a Danish inventor who produced machines and developed the technology. After a promising start the activity became embroiled in legal and patent problems which delayed the development. Despite this, as the legal problems were resolved, and the technical and engineering problems were slowly eliminated, a number of web producers became interested in the application of this technology to produce wide continuous rolls of low-density webs based on cellulose with various types of bonding of the sheet.

Two Danish companies, M&J Fibretech [3] and DanWebforming [4] have both made significant contributions to the development of the machines required for the production of these new web structures. A machine configuration based on the M&J system is shown in Fig. 5. Figure 5 illustrates how wood pulp, synthetic fibre, binder fibres and granular superabsorbent materials may be combined into a multilayer composite material. The composition of each layer may be different, for example all of the required superabsorbent may be added

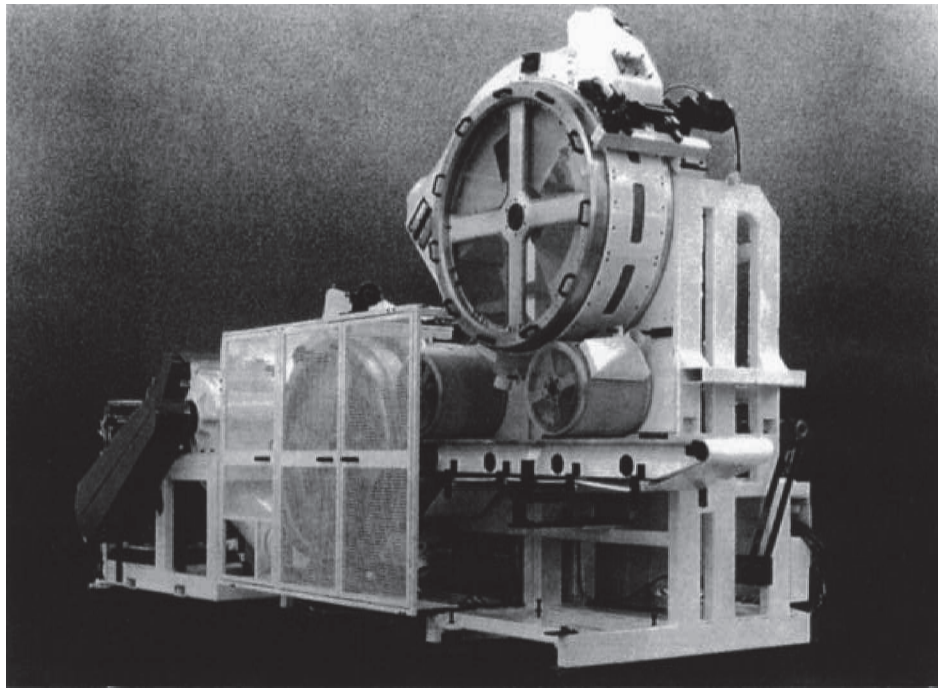


Fig. 4 Drum pocket former for the production of absorbent core pads

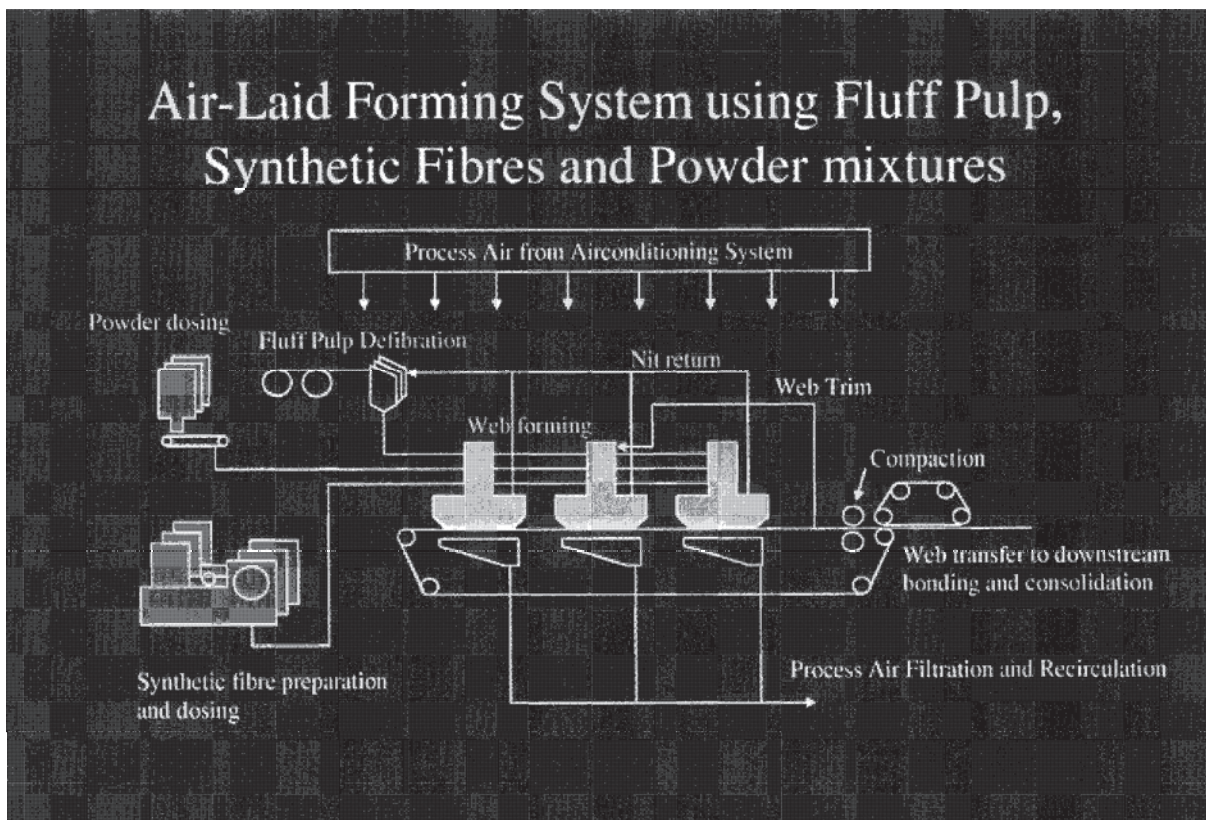


Fig. 5 M&J FibreTech configuration of a multilayer machine system to produce absorbent composite material

to the middle layer or to only the bottom layer, depending on the finished product requirements. This emerging technology uses the concept of suspending selected fibrous (and, when required, non-fibrous) materials in an air stream and supplying that dispersion to a series of forming zones on the machine where the fibres would be deposited onto a moving porous belt. It can be seen that it is also possible to insert pre-formed web material into the structure [5, 6].

As dry defibred cellulose fibres have little ability to bond together (unlike wet dispersed cellulose fibres which show a ready ability to form hydrogen bonds), other types of bonding have to be introduced. Bonding the fibres together into a coherent web structure could be achieved by the application of a water-based emulsion of polymer known as a latex, by the addition of thermally meltable components in the web forming and then heating the web to the melting point of that component. Alternatively, bonding could be achieved by high-intensity hydrogen bonding with the addition of a small amount of water to the web surface and use of a high-intensity heated calender with an engraved roll. For some product types a combination of bonding systems is used to achieve the required product properties.

Multiple forming heads (Fig. 6) allow different fibres to be used in each forming head. These structures can then be combined with pre-formed webs produced by other technologies, i.e. spunlaid polypropylene non-woven, and other non-fibrous materials can be added as the composite structure is formed. This leads the way to the production of composite, multiprocess, multilayer products where specific performance characteristics may be built into each layer (see Fig. 7). These early products were attractive to the feminine hygiene product sector as the pre-formed webs provide a more uniform absorb-

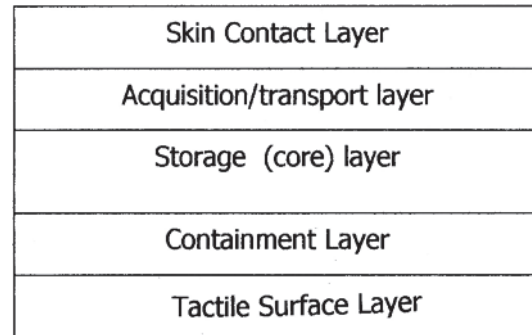


Fig. 7 Diagram of a multifunctional, multilayer product structure

ent core structure for their products. Their use also resolved a worrying problem associated with the use of granular superabsorbent polymers 'migrating' to the top skin contact layer in thin feminine hygiene products, by sandwiching the polymer within the central layer structure of the pre-formed web. The first stage of the application of this technology in adult incontinence products is now underway with a limited number of producers using pre-formed core products in their disposable products for the management of light incontinence [7, 8]. The big advantage of this technology is that it is possible to produce a much more uniform structure with web weight variation of ± 2 per cent. It is also possible to produce this material on wide (3–4 m) machines and with a reasonably fast output rate [9]. Couple this with the opportunity to combine a wide variety of materials into one composite structure and the potential can be readily recognized. A number of companies are now producing core replacement and other more complex structures on a commercial scale; however, it must be added that there

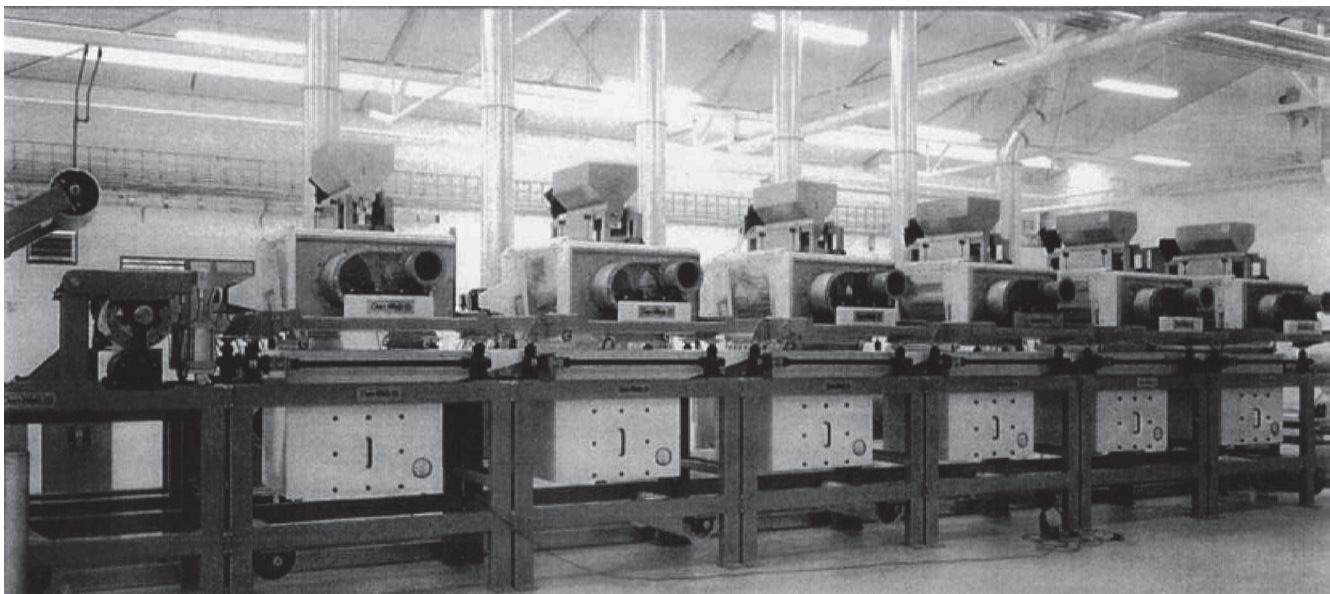


Fig. 6 DanWebforming multiple head forming section for composite manufacture

are still a number of problems to be resolved before the application of these composite materials can really gather momentum. These problems are not primarily concerned with forming the composite structures, but rather in the area of handling the large wide reels of low-density product produced (see Fig. 8), the transport of such materials from manufacturing site to converting factory and the effective handling of production waste.

5 CONCLUSION

The short-fibre airlaid technology, as represented by the M&J Fibreweb and DanWeb technology described in this paper, represents an alternative route for the production of single-use absorbent hygiene products which overcomes or reduces some of the problems associated with the current assembly method.

The use of pre-formed composites makes a major



Fig. 8 'Superspool' concept for handling and shipping large rolls of absorbent products

impact on the pad weight variation problem and the associated variations in web weight related properties. The effect that better control of the pad weight has on manufacturing waste is significant and results in worthwhile financial savings [10]. In addition, better weight control in the individual component layers and the opportunity to reduce web weights to remove the overengineering of these layers [11] to accommodate running the individual webs through the converting unit, offers additional financial benefits as well as improved technical performance.

By constructing a composite web [12] *in situ*, the performance of each component layer can be optimized for the primary task that it is expected to do in the finished product, for example, the acquisition/transport layer can be optimized with respect to pore structure and wicking performance without regard to web strength.

There are a number of difficult problems still to be resolved, but the availability of composite structures in roll form is allowing product development work to proceed. A number of products for the management of light incontinence are now available [13]. There are also a number of problems still to be resolved in areas of materials handling and transport, but the cost benefits and control improvements have been shown to be real. It is therefore to be hoped that the application of this technology will result in thinner, more functionally refined products becoming available for the management of adult incontinence problems. Current producers have to face a difficult choice: to continue to develop the existing technology based on the assembly-line concept, or to reinvest in converting to systems which offer much more in the way of future potential. In these uncertain economic times, this is a particularly difficult problem to resolve, but longer term it is to be hoped that the emerging developments in this area do not falter and that new generation products will be achieved.

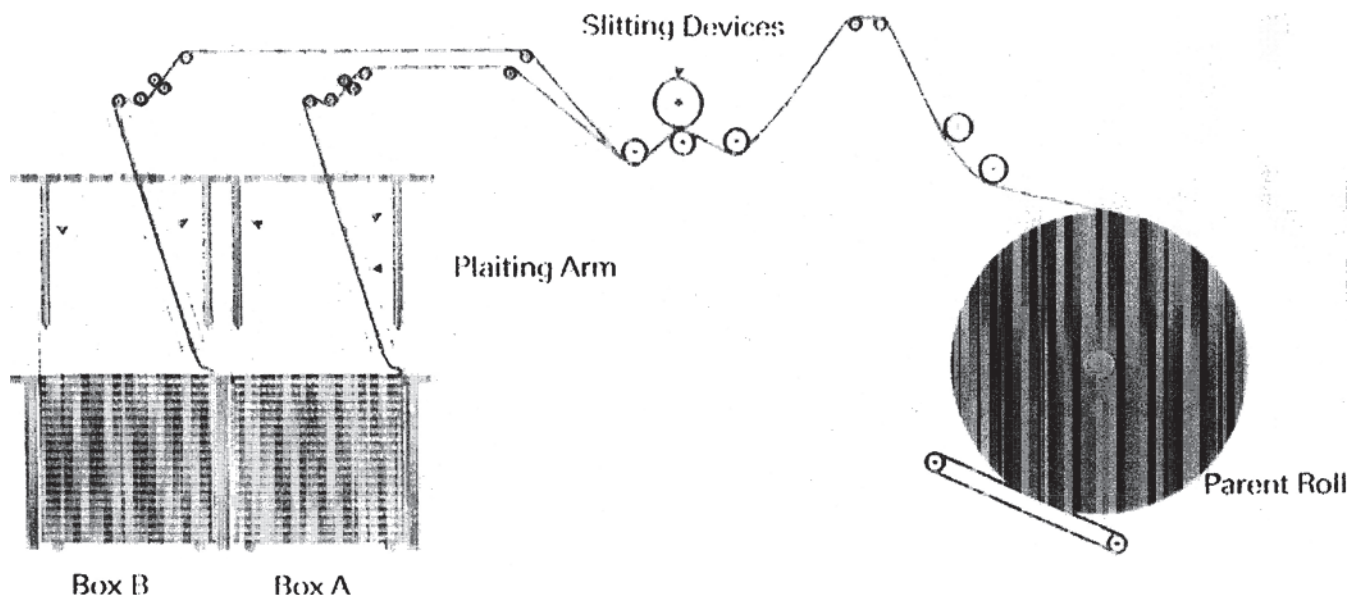


Fig. 9 Festooning system for handling composite materials

6 FUTURE DIRECTIONS

The application of multilayer composite webs to the production of disposable absorbent hygiene products for the management of adult incontinence has been shown to be a potentially attractive alternative manufacturing system. There are a number of problems still to be overcome and questions to be answered before the full potential of this technology can be realized.

Some of these questions are listed below.

1. The correct formulation of the individual plies and the way in which the layers interact with each other needs a better understanding of the fluid dynamics of such systems so that the use of more expensive component materials required in some layers can be optimized.
2. The whole question of handling the 'jumbo'-size reels off the production unit through to the converting operations of slitting and rewinding needs further study to minimize waste.
3. The ability to supply continuous feedstock to the conversion unit requires further study to ensure uninterrupted running without frequent feedstock changes and consequent downtime.
4. The optimum reuse of production waste needs to be studied to determine the best and most effective way to use this mixed-component material.
5. The process economics of both the existing assembly-line systems and the new alternative systems need to be examined on a strictly comparable basis to establish the system costs and potential savings.
6. A cost/benefit analysis of the alternative technology needs to be independently assessed to provide an acceptable financial basis for new investment.

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