

# Evaluating effect of hydraulic characteristics of various top sheets on performance of Sanitary Napkins

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## ABSTRACT

Textiles have a significant role in helping women to overcome a various challenges pertaining to their health and hygiene. Various hygiene textiles including sanitary napkins help to preserve women's health and cleanliness during their menstrual period against the blood and fluid discharge which occurs monthly from puberty to menopause phase. For comfort and to maintain routine day to day activities, the discharged fluid needs to be absorbed by various absorbent materials used in the sanitary towels, tampons etc. The sanitary napkin attends to the drive of engrossing and retaining the period blood while also keeping it away from the body surface. The hydraulic characteristic viz. absorption and rewetting are very important for the proper performance of the sanitary napkins. A sanitary napkin consists of multiple layers, mainly a top sheet, absorbent core, and back sheet. The upper layer of a sanitary napkin significantly influences user's comfort, fluid absorption capacity, and the product's rewet properties.

In light of escalating environmental concerns, the sanitary product sector is progressively exploring sustainable substitutes for the traditional synthetic top sheets currently employed. This research aims to assess and contrast the efficacy of biodegradable top sheet materials in sanitary napkins against conventional top sheet materials, emphasizing essential functional parameters such as absorption rate, overall absorbency, and rewet. Total of eight top sheet samples: five made of using synthetic polymer and three made from natural polymers have been used for the study. Both these types of material underwent uniform test procedure for comparison of hydraulic characteristics and their effect on performance of the final products.

The biodegradable top sheet shows a better absorbency, it may often feel wet again after use due to their high rewet values. Overall performance of cotton, silk, and corn top sheets found better or at par with the synthetic top sheet products. The sanitary napkins made from the natural fiber top sheet also showed much better absorbency properties and liquid holding capacity. This study is helpful in designing the new sanitary products with wider choice of natural fibrous materials. The results show that one can make use of biodegradable materials for comforts, performance and eco-friendly sanitary napkins. This points toward a better future where feminine hygiene aspect is much safer for the people and planet.

## Introduction

Sanitary napkins, commonly known as sanitary pads, sanitary towels, maxi pads, menstrual cups, tampons are essential to maintain reproductive organ's cleanliness in case of women especially during menstrual period. The Sanitary napkins are single use disposable textile that, receive, absorb, and retain the menstrual discharge safely evacuating from the body surface [1]. Unlike tampons and menstrual cups, which are inserted into the vagina, sanitary napkins are worn externally, next to a woman's vulva inside the undergarment [2]. A sanitary napkin is multi layered structure viz. top sheet, core layer, and back sheet as illustrated in (Fig. 1). Each of these elements plays a crucial role in shaping the comprehensive efficacy of the product. Generally, the top sheet used for sanitary pads is light weight as compared to that used in baby diapers, and was formerly thought to have the highest absorbency [3, 4]. The top sheet should be soft, porous, and hydrophilic in order to provide comfort, quick transmit of menstrual blood from body surface to core absorbent layer and prevent it backflow [5].

The core layer is comprised of super absorbent polymer (SAP) integrated in a fluffy cellulose matrix. This layer is responsible for absorbing and storing the collected discharged blood. Since less fluid is expected to be handled, the absorbent layer of a napkin is also thinner than that of a diaper [6]. Frequently, a nonwoven construction with several sub-layers and a gradient in pore size accomplishes this purpose in both this layers (Fig. 2). The fluid flow is better, the higher the pore size and porosity whereas fluid holding capacity increases with high density of the layer.

The back sheet is an impermeable thin film or fabric, serving as a barrier to prevent fluid leakage. A breathable yet liquid impermeable film often composed of polyethylene [7]. The bottom part of the napkin frequently coated with a layer of adhesive to make sure the napkin stay at its designated position in undergarment [8, 9].

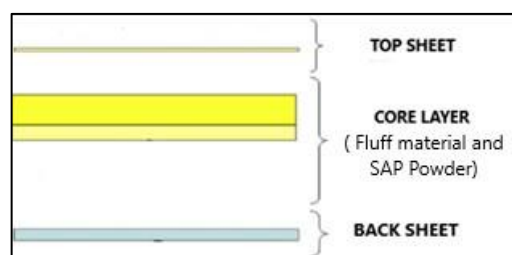


Fig. 1. Layer construction of disposable sanitary napkin

The goal of this study is to design a sanitary napkin using indigenous natural polymeric materials to replace the synthetic polymers, currently used for the top sheet of sanitary napkins used globally.

#### Literature review

D. Pradhan, et al. [10] presents a theoretical model for water absorption in nonwoven materials, validated by experiments on polyester fibers with different sizes and porosities. The model accurately explained the results, showing that both absorption capacity and rate increase with higher porosity. Additionally, finer fibers led to greater absorption capacity and faster absorption rates.

Jeyakanthan D. M., et al. [11] conclude that the biodegradable pads are better for both people and the environment. This study made biodegradable pads in three sizes using materials that support a healthy menstrual cycle and break down quickly, reducing landfill waste. They concluded that biodegradable pads are better choice, and future research may explore shredded fibers instead of carded fibers for the absorbent core. Rastogi D., et al. [12] studied and found that corn husk fibers could be a good alternative for use in hygiene products like sanitary napkins, diapers, and absorbent sheets. More research is needed to find the best way to make sanitary napkins with corn husk fibers so they can be used widely and help save natural resources, since corn husk is usually waste.

Culfa G. et al. [13] used a new air laid composite nonwoven as the inner layer of sanitary napkins in their study found an alternative to the usual types. The results showed that napkins with this new inner layer had higher liquid strike-through time, rewet, and menstrual fluid spreading compared to napkins with the regular ADL+Core inner layer. They concluded that the air laid composite layer could be a good alternative if its liquid strike-through time is improved.

Choudhary J. & Bhattacharjee D. M. [14] studied the consumption pattern of sanitary napkin and environment degradation analysing the secondary data linking the sale data of manufactures. They concluded that more than 60% were aware that synthetic sanitary napkins cause environment pollution; whereas only 30% of women know about eco-friendly pads.

A recent studies show that increasing consumption of menstrual products especially sanitary napkins have an adverse effect environment due to huge amount of synthetic materials, energy, and water consumed. Disposable sanitary goods including sanitary pads contain up to 50% plastic viz. rayon mixed with the Polyethylene and polypropylene, most of these end up in landfills [15].

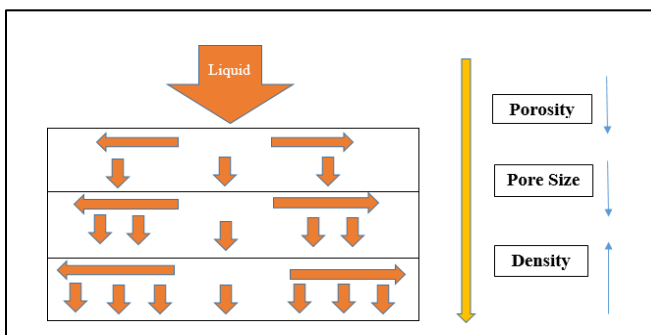


Fig. 2. Mechanism of fluid flow through layers of sanitary napkin

#### Materials and Methods

Various samples of sanitary napkins were prepared using different types of top sheets using Hen-chang machine, HCH Ltd., at SIPL Industries Pvt. Ltd., Ahmedabad. To evaluate the effect of various parameters of top sheets, main hydraulic properties, such as liquid strike through and wet back have been measured critical to effectiveness of sanitary napkins. The performance characteristics of sanitary napkins have been studied by absorbency and rewet tests. The results can indicate how fast the pad can absorb and how much fluid it can hold; which decides the comfort of users by providing dry condition against the discharge. As pad has to perform for longer duration, these tests have been conducted for two cycles. The fluid transmission capacity of sanitary napkins also have been measured using synthetic blood

#### Top Sheet

A total of eight different top sheets materials have been selected in this study, varying in terms of polymer type, fabric structure, and method of manufacture. The specifications of this top sheet are given in Table I. The brief description of these samples have been given as under.

Spun-laid nonwoven also known as spun-bond nonwovens produced by a continuous manufacturing process in which the fiber are predominantly spun and subsequently dispersed into a sheet using deflectors. The uppermost very thin layer consists of hydrophilic absorbent fibers along with the hydrophobic layer (TS<sub>1</sub>).

Hot air-through nonwoven fabric is made utilizing air-through-bonding technique used for synthetic polymeric fibers. This is a type of nonwoven fabric frequently referred to as Hot Air Cotton in the health and hygiene industries made normally entirely using Polypropylene (TS<sub>2</sub>).

Single PPF (perforated poly films), are a type of plastic film commonly used in the manufacturing of feminine hygiene products like sanitary napkins. These films provide an effective moisture barrier that efficiently prevents any leakage, ensuring the wearer's dryness and comfort. PE films are typically produced from extrusion using HDPE or LDPE resin (TS<sub>3</sub>).

Double perforated, or micro-perforated polymer film, is also produced by cast film extrusion using polyethylene. The molten polymer resin is forced out through a die and subsequently formed into a film. The film is then punctured using a vacuum (TS<sub>4</sub>).

TABLE I. SPECIFICATIONS OF POLYMER AND FABRIC TYPE OF TOP SHEET.

| Sr. No | Top sheet material             | Product code    | Method of manufacture                   |
|--------|--------------------------------|-----------------|-----------------------------------------|
| 1      | PP Spun-bond nonwoven          | TS <sub>1</sub> | Thermally sealed spun-bonded nonwoven   |
| 2      | PP Hot air through nonwoven    | TS <sub>2</sub> | Hot air thermally bonded nonwoven       |
| 3      | PE Single perforated poly-film | TS <sub>3</sub> | Cast film extrusion                     |
| 4      | PE Double perforated poly-film | TS <sub>4</sub> | Cast film extrusion                     |
| 5      | PE:PP Laminated composite      | TS <sub>5</sub> | Thermally laminated PE with PP nonwoven |
| 6      | Organic cotton nonwoven        | TS <sub>6</sub> | Spun-laced nonwoven                     |
| 7      | Mulberry silk nonwoven         | TS <sub>7</sub> | Spun-laced nonwoven                     |
| 8      | Corn- PLA nonwoven             | TS <sub>8</sub> | Spun-laced nonwoven                     |

The film can be perforated having perforations in several shapes, including circular, square, pentagonal, elliptical etc. The double perforated poly top sheet also has been procured from Tredegar Corporation, USA. PE laminated non-woven fabric refers to a nonwoven fabric that has been coated with a layer of plastic film. Typically, the plastic is heated to its melting temperature, and applied onto the nonwoven fabric the cooled down to room temperature coating the surface forming the laminated fabric (TS<sub>5</sub>).

The organic cotton nonwoven is a sustainable and eco-friendly choice for personal hygiene applications. The fabric is made exclusively from unbleached organic cotton fibers using spun-lace process of nonwoven manufacturing leading to the presence of smooth fiber fringe spots on the fabric's surface (TS<sub>6</sub>).

The mulberry silk spun-lace nonwoven fabric possesses excellent moisture absorption and air permeability. It also has a soft handle, high strength, super draping properties, and does not require adhesive reinforcement (TS<sub>7</sub>). Polylactic acid (PLA), referred to as corn fiber used in spun-laced nonwoven (TS<sub>8</sub>) possesses exceptional characteristics such as outstanding drape, slide, moisture absorption, and breathability. It exhibits natural bacteriostatic and weak acidity, which provide relief to the skin. Additionally, PLA fiber demonstrates good heat resistance and UV resistance.

In conventional sanitary pads, the absorbent core layer is usually made of air-laid paper and SAP (superabsorbent polymer) paper. In biodegradable sanitary napkin uses bamboo fiber sheets and corn starch sheets, which are eco-friendly and biodegradable materials.

The back sheet is the bottom layer of a sanitary napkin that stops liquid from leaking out. It is usually made of polyethylene (PE). In this study, PE is used for regular pads, while PLA and PBAT are used as biodegradable options.

It is made using a PE film that lets air pass through but retain the liquid. It protects the absorbed fluid from getting contaminated or leaking. The choice of biodegradable plastics is the combination of polymer blends such as poly (butylene adipate-co-terephthalate) (PBAT) and polylactide (PLA). These capture attention as hygiene barrier films. The molecular weight of PLA has been 5-6 times better than the normal plastic items.

#### Liquid strike through

All these type of top sheet performed the strike through and wet back testing as per the EDANA standard. Strike through time, also known as penetration time, is the amount of time it takes for a liquid to pass through the top layer of a product, such as a sanitary napkin, and get absorbed into the absorbent core. It is measured in seconds and helps to understand how quickly the product can absorb fluid when it comes in contact with it.

#### Wetback

Wetback, also called rewet, is a measure of how much liquid comes back out of a product, like a sanitary napkin, after it has already absorbed the fluid. When weight is applied to the product, similar to the pressure from sitting or moving. The liquid that comes back out can make the surface feel wet and uncomfortable, which is why it's important to keep this amount as low as possible. The wetback is measured in grams and tells us how much fluid is released back onto the skin. This test follows a standard method called NWSP 80.10.R0 (15), which ensures the results are accurate and consistent. A lower wetback

value means the product keeps the skin drier and is more comfortable to use.

#### Absorption and rewet

Absorbency and rewet tests were then carried out to assess how well each napkin could absorb liquid and how much liquid came back to the surface. There are different methods used to measure how well sanitary pads can absorb and hold liquid without leaking. These techniques help test how much fluid a product can take in and keep inside, which is very important for keeping the user dry and comfortable. These Absorption and rewet tests help decide the products perform well in actual circumstances.

#### Results and Discussion

This research evaluated sanitary napkins constructed from various top sheet materials, concentrating on five key characteristics, including strike-through time and rewet for the top sheets, along with absorption, rewet, and fluid distribution for the sanitary napkins. Various ultra-thin napkins samples, have been prepared using eight different types of top sheet as given in Table II. Various absorption properties have been measured for two cycles for each sanitary napkins sample are given in Table 3 III.

Table II shows the properties of eight different nonwoven top sheets used in sanitary napkins, focusing on strike-through time, and wet back. Strike-through time tells how quickly liquid passes through the top layer. The nonwoven sample TS<sub>1</sub>, and TS<sub>6</sub> shows 1.8 s and TS<sub>8</sub> shows only 1.7 s, the shortest among all, absorbing the fluid much quicker providing the dry surface. Whereas sample TS<sub>3</sub> and TS<sub>4</sub> show 3.6 s and 3.3 s respectively; slowest among to its structure; extruded film having water resistant surface that delay absorption. Top sheets TS<sub>3</sub>, TS<sub>4</sub> and TS<sub>8</sub> show very low wet back mass due to higher resistant to flow of liquid. These materials retain fluid well once observed. Sample TS<sub>1</sub> and TS<sub>2</sub> give high wet back value, indicates not able to hold the absorbed liquid.

Table III shows the performance of eight sanitary napkins based on absorption time, rewet, and fluid distribution. SN<sub>6</sub>, SN<sub>7</sub>, and SN<sub>8</sub> had the fastest absorption times in both cycles, meaning they soaked up liquid quickly. SN<sub>3</sub> and SN<sub>4</sub> took the longest time to absorb, which may lead to discomfort or leakage. In terms of rewet, SN<sub>3</sub> and SN<sub>2</sub> performed best with the least liquid returning to the surface, showing good dryness.

TABLE II. DETAIL SPECIFICATIONS OF VARIOUS NONWOVEN TOP SHEETS

| Sr. No | Top sheet code  | Mass density (gsm) | Strike through (s) | Wet back (g) |
|--------|-----------------|--------------------|--------------------|--------------|
| 1      | TS <sub>1</sub> | 18.1               | 1.8                | 0.9          |
| 2      | TS <sub>2</sub> | 18.2               | 2.4                | 0.8          |
| 3      | TS <sub>3</sub> | 20.0               | 3.6                | 0.0          |
| 4      | TS <sub>4</sub> | 20.0               | 3.3                | 0.1          |
| 5      | TS <sub>5</sub> | 30.0               | 2.5                | 0.1          |
| 6      | TS <sub>6</sub> | 30.0               | 1.8                | 0.6          |
| 7      | TS <sub>7</sub> | 30.0               | 2.0                | 0.4          |
| 8      | TS <sub>8</sub> | 30.0               | 1.7                | 0.1          |

TABLE III. ABSORPTION PROPERTIES FOR THE VARIOUS SANITARY NAPKINS

| Sr No | Napkin code     | 1st cycle absorbent time (s) | 1st cycle rewet (g) | 2nd cycle absorbent time (s) | 2nd cycle rewet (g) | Distribution length (mm) |
|-------|-----------------|------------------------------|---------------------|------------------------------|---------------------|--------------------------|
| 1     | SN <sub>1</sub> | 17.14                        | 1.53                | 23.08                        | 5.14                | 150                      |
| 2     | SN <sub>2</sub> | 23.12                        | 0.82                | 36.40                        | 3.00                | 165                      |
| 3     | SN <sub>3</sub> | 30.14                        | 0.72                | 44.16                        | 2.81                | 163                      |
| 4     | SN <sub>4</sub> | 28.92                        | 0.90                | 43.76                        | 3.00                | 166                      |
| 5     | SN <sub>5</sub> | 24.86                        | 0.97                | 37.32                        | 3.35                | 169                      |
| 6     | SN <sub>6</sub> | 11.50                        | 1.48                | 20.14                        | 3.53                | 171                      |
| 7     | SN <sub>7</sub> | 14.82                        | 1.85                | 21.96                        | 3.40                | 168                      |
| 8     | SN <sub>8</sub> | 12.00                        | 1.46                | 20.48                        | 3.41                | 173                      |

SN<sub>1</sub> had the highest rewet value in the second cycle (5.14 g), which means it may feel wet and uncomfortable. SN<sub>8</sub> had the longest distribution length (173 mm), showing that it spread liquid well across the pad. SN<sub>1</sub> had the shortest distribution (150 mm), meaning liquid stayed in one area and may cause leaks. Overall, SN<sub>6</sub>, SN<sub>7</sub>, and SN<sub>8</sub> gave good results in fast absorption and spreading. SN<sub>3</sub> and SN<sub>2</sub> were better at keeping the surface dry. SN<sub>1</sub> showed the weakest performance in all areas.

### Conclusion

In the present study various top sheets have been tested for their hydraulic characteristic performing strike through and wet back test. Moreover each napkin sample have been evaluated for absorption and rewet characteristic for two cycle. The liquid distribution along the plane of pad also have been measured as distribution length. Following conclusion may be draw form the study.

a) Among the various synthetic top sheets, thermally sealed spun bonded PP top sheet showed better performance than that of other synthetic PP/PE hot air bonded, extruded film or thermally laminated top sheets. Whereas all natural fiber top sheets prepared using spun laced technique, showed much better absorption. However cotton and corn nonwoven sheet showed the best absorption characteristics.

b) Perforated HDPE / LDPE polyfilm top sheets show longer strike through time i.e. transit the liquid slowly but their rewet properties are excellent keeping the surface dry providing better comfort to user. The double perforated top sheet shows marginally better strike through time than that of single perforated extruded film.

c) Cotton, silk, and corn- PLA spun laced nonwoven top sheets are having smooth surface and have satisfactory wet back results. These materials are better option to the synthetic top sheet materials leading to use the use of eco-friendly sanitary pads.

d) The sanitary napkins made from the natural fiber top sheet also showed much better absorbency properties including

liquid distribution length thus liquid holding capacity found better than that of synthetic top sheet pads.

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