Effects of liquid ammonia treatment on the physical properties of knit fabric

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Abstract. The cellulosic knit fabric must be treated by NaOH solution in silket process to modify dyeability, luster, physical property, etc. But the silket treated knit fabric has a stiff touch, and must be treated with much of silicone softener. But it has bad durability of laundry. And the silket process has a problem that must discharge a lot of alkaline wastewater. In case of woven fabrics, as an alternative to silket process, liquid ammonia process was developed and this process is eco-friendly because the used ammonia is recovered by 98%. But the knit fabrics are not applicable to the conventional liquid ammonia process because they have selvedge curling problem and are very sensitive to tension. Recently, Korea High Tech Textile Research Institute(Korea) and Lafer SPA(Italy) worked together to develop the new liquid ammonia process for knit fabrics. In the present study, the physical properties of knit fabric after the newly-developed liquid ammonia treatment were investigated. The basic physical properties of knit fabric were measured using the Kawabata evaluation system. In addition, the dyeability, dimensional stability, eco-friendliness were investigated. The results showed that liquid ammonia treatment gave improved physical properties, which can be attributed to fast and uniform swelling, to knit fabric and resulted in a dimensional stability. The knit fabric treated in liquid ammonia showed a darker colour and unique appearance. Above all, the knit fabric treated in liquid ammonia had softer touch and superior gloss than the knit fabric of silket process. The new liquid ammonia process for knit fabrics will become the highest quality standard for knits and will be considered the preferred finish also thanks to eco-friendliness.

1. Introduction

Recently, a liquid ammonia process has been receiving much attention as a new environment friendly aftertreatment of woven fabric. The liquid ammonia has the boiling point of -33.4 degrees Celsius and the surface tension is 0.0334 N/m, which generates faster penetration than sodium hydroxide, reaching the swelling in a short period of time with uniform results after the treatment [1]. The reaction between liquid ammonia and cellulose has been known since 1930s but recently it has been receiving much attention in the aspect of excellent hand realization. In addition, its characteristics include low reduction of strength, high crease resistance, easy-care to cotton fabrics, and high recovery rate from the complete recycle system, making it an environment friendly process [2-4].

The cellulosic knit fabric must be treated by NaOH solution in silket process to modify dyeability, luster, physical property, etc. But the silket treated knit fabric has a stiff touch, and must be treated with much of silicone softener. But it has bad durability of laundry. And the silket process has a problem that must discharge a lot of alkaline wastewater.
In case of woven fabrics, as an alternative to silket process, liquid ammonia process was developed and this process is eco-friendly because the used ammonia is recovered by 98%. But the knit fabrics are not applicable to the conventional liquid ammonia process because they have selvedge curling problem and are very sensitive to tension. Recently, Korea High Tech Textile Research Institute (KOTERI)(Korea) and Lafer SPA(Italy) worked together to develop the new liquid ammonia process for knit fabrics. In the present study, the physical properties of knit fabric after the newly-developed liquid ammonia treatment were investigated. The basic physical properties of knit fabric were measured using the Kawabata evaluation system. In addition, the dyeability, dimensional stability, eco-friendliness were investigated.

2. Experimental

2.1. Materials
Cotton knit fabric used in the study is CM 30’s single jersey knit with 60inch of width and 140g/m².

2.2. Conditions of liquid ammonia treatment of knit fabric
For the liquid ammonia treatment, the world-first commercial equipment for knit by Lafer spa, currently being operated in KOTERI, was used, and the ammonia was all evaporated by passing through the drying and steaming zone with the production rate of 18m/min. Drying and steaming temperature are 130 and 120 degrees Celsius, respectively. The drawing and actual photo of the world-first liquid ammonia equipment are as shown in Figure 1.
Figure 1. World-first liquid ammonia treatment machine for knitted fabrics
2.3. Dyeing conditions of knit fabric treated in liquid ammonia
For the dyeing of knit fabric, Cold-Pad-Batch (CPB) dyeing method was used. Dyeing conditions are as shown in Table 1 and the photos of the actual CPB process are presented in Figure 2.

| Yarn type | Speed | Pick-up (%) | Batching Time | Batching Temp. |
|-----------|-------|-------------|---------------|---------------|
| CM 30’s   | 25m/min | 100         | 16 Hours      | 25 °C         |

Table 1. Dyeing conditions of knit fabric

Figure 2. CPB Dyeing process for knit fabric

2.4. Measurement of physical property
The measurement of physical properties was conducted using the KES-FB system (Kawabata Evaluation System for Fabric, Kato Tech. Co. LTD), which was suggested by the Hand Evaluation and Standardization Committee in Japan. The tensile property, bending property, shear property, compression property, surface property, and thickness and weight (6 properties, 17 items) were measured for each warp and weft directions at the standard conditions. The size of the samples used was 20×20cm, and samples were conditioned at standard condition prior to experiments. Study is concentrated on bending and shear properties that influence on the handle and touch of fabric. And bursting and tensile strength are measured separately.

2.5. Measurement of surface color
To measure the surface color changes by the process, the color difference meter (Color Eye 7000A, gretagmacbeth) was used. The spectral reflectance (R) was measured at the light source of D65, observation view of 10° and at the maximum absorbance wavelength, then K/S value was obtained using the Kubelk-Munk equation for evaluation of the dyeing property.

2.6. Measurement of dimensional stability
Dimensional stability was measured to evaluate the shrinkage of knit fabric after laundering. The test method is accomplished by AATCC 135.

2.7. Investigation of Eco-friendliness
Eco-friendliness was investigated to evaluate the manufacturing cost compared to the conventional process (mercerization).
3. Results and discussions

3.1. Physical property

3.1.1. Bending property

Bending property is an important property to determine various practical characteristics of fabric including the hand, drape, clothing formation performance, dimension stability, appearance of clothing and crease restoration. It is closely related to the fitness performance in the wearing process which is a continuous process of transformation and restoration, and a property to show the extent of fusion with the curve of human body. The bending property is expressed in bending strength (B) and bending hysteresis (2HB) [5]. The bending strength (B) is affected by contact pressure and density, contact field, thickness of thread between fibers and yarns. It has impact on the sewing as well as formation performance and hand of fabrics. A greater value means that the material is stiff and a smaller value represents outstanding performance of curve formation. Bending hysteresis (2HB) represents the proportional relations with the energy loss in the process of bending strains and restoration, where a smaller value means the extent of restoration from the bending change is more elastic. Results of the measurement are as shown in Figure 3. Untreated sample that means the pre-scoured knit fabric before liquid ammonia treatment showed the lower values indicating the liquid ammonia (LAMP) treated sample became a little stiffer after process treatment.

![Figure 3. Results of bending property](image)

3.1.2. Shear property

The shear property is a transformation to the external force that extended samples, and is a factor affecting the appearance of the curve or change in the human body when clothing is worn along with the bending property. Shear hysteresis is an important factor in the crease of fabrics [6]. Shear property is characterized by the shear stiffness (G), shear hysteresis (2HG). Shear stiffness (G) is a change by a shear force, and a small value means easy changes can occur. The shear hysteresis (2HG) and the hysteresis (2HG5) at the shear angle 5° represent the magnitude of energy loss for restoration after shear change. A small shear hysteresis means there is no difference in shear force at the initial direction and restored direction, showing elastic restoration. Results of the measurement are as shown in Figure 4. Untreated sample showed the lower values in broad lines indicating the liquid ammonia treated sample became a little stiffer and more elastic power after process treatment.
3.1.3. Bursting and tensile strength
The bursting and tensile strength of fabric material depends on the linear density of thread, number of strands of wale and course. It is an important behavior to determine the drape, hand, sewing, wrinkles, and stability of fabrics [7]. Results of the measurement are as shown in Figure 5. Untreated sample showed the lower values indicating the liquid ammonia treated sample became stronger and more elastic power after process treatment.

![Bursting strength](image1)
![Tensile strength](image2)

Figure 4. Results of shear property

Figure 5. Results of bursting and tensile strength

3.2. Dyeability (Surface color)
Surface colors were measured to evaluate the changes of knit fabric colors by the process and the results are shown in K/S values. As shown in Figure 6, the LAMP treatment increased the K/S values showing darker colors.
3.3. Dimensional stability (Shrinkage)
Dimensional stability was measured to evaluate the shrinkage of knit fabric after laundering. As shown in Table 2, the LAMP treatment improved the shrink-proof property.

Table 2. Results of shrinkage

| Direction | Shrinkage(%) | untreated | LAMP treated |
|-----------|--------------|-----------|--------------|
| Wale      | -9.7         | -1.7      |              |
| Course    | -5.0         | -4.1      |              |

3.4. Investigation of Eco-friendliness
Eco-friendliness was investigated to evaluate the manufacturing cost compared to the conventional process (mercerization). Save (%) was calculated with the cost for each row. As shown in Table 3, the LAMP treatment has a merit of eco-friendliness compare to the conventional process. In the view of total cost, while the total Mercerizing process cost is 309.7$, the total Liquid ammonia process cost is 73.82$. So the total save (%) is 76.2%.

Table 3. Results of Eco-friendliness and cost save(%)

|                     | Mercerizing(Silket) process | Liquid ammonia process | Save(%) |
|---------------------|-----------------------------|------------------------|---------|
|                     | Demand amount               | Cost($)                | Demand amount | Cost($) |       |
| Water               | 30.6ton                     | 7.6                    | 0.25ton     | 0.06    | 99.2   |
| Steam              | 3.6ton                      | 100                    | 1.5ton      | 33.3    | 66.7   |
| Auxiliary          | 450kg(NaOH)                 | 171.9                  | 0.7kg(NH3)  | 0.9     | 94.9   |
| Electricity        | 180kWh                      | 12.4                   | 570kWh      | 39.4    | -216.7 |
| Wastewater         | 30.6ton                     | 17.8                   | 0.25ton     | 0.16    | 99.2   |
| Total              | -                           | 309.7                  | -           | 73.82   | 76.2   |
4. Conclusion
In the present study, the physical properties of knit fabric after the newly-developed liquid ammonia treatment were investigated. The basic physical properties of knit fabric were measured using the Kawabata evaluation system. In addition, the dyeability, dimensional stability, eco-friendliness were investigated. The results showed that liquid ammonia treatment gave improved physical properties, which can be attributed to fast and uniform swelling, to knit fabric and resulted in a dimensional stability. The knit fabric treated in liquid ammonia showed a darker colour and unique appearance. Above all, the knit fabric treated in liquid ammonia had softer touch and superior gloss than the knit fabric of silket process. The new liquid ammonia process for knit fabrics will become the highest quality standard for knits and will be considered the preferred finish also thanks to eco-friendliness.

5. References
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