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Washing Chemistry Factors Impact on Wool Fabric Shrinkage

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ABSTRACT

The washing Chemistry Variables such as water, mechanical agitation, temperature, and spinning are responsible for the efficient washing of fabrics but may cause fabric shrinkage. This study intends to investigate the washing variables above and washing programs designed by the manufacturer so that the textile care service providers may have depth knowledge of their roles in maintaining delicate fabrics such as wool and preventive measures. The approach to this method is an experimental study. The variables under investigation were subjected to real-life washing operations in a washer extractor under varying conditions at a constant load for gravitation effects. The results showed that the machine manufacturer's program for wool does not prevent wool shrinkage. Also, the findings indicated that percentage area shrinkage increases as the temperature rise from 300C to 400C, and area shrinkage steadily approaches equilibrium at 600C. Furthermore, findings suggested that percentage area shrinkage was not directly proportional to an increase in spinning speed. Machine default programs variables manipulation indicated a significant reduction in fabric shrinkage provided other variables remained fixed.

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Introduction

Wool fabric fiber is a polymer composed of a protein chemical structure of amino acids known as keratin. Wool fabric has inherent warm properties that make it suitable for different garment production, especially during cold weather. Its uses in outer-wear include sweaters, suiting materials, or jackets. Due to its tendency to undergo shrinkage during fabric care, wool is often subject to dry-cleaning operations rather than wet processes such as laundry. The degree of shrinkage in the dry-cleaning operation is not as disturbing as the laundry processes that use water and detergent.

However, microscopic examination of wool fiber surface has shown the presences of scales, which many literatures suggest are responsible for shrinkage. Because of this, wool fabric production may include a de-scaling operation that removes directional scales on the wool fiber surface using sodium hypochlorite solution. This attempt to reduce shrinkage in wool during laundry operations. Another concern is that wool fiber loses strength when wet in water rather than dry-cleaning solvents.

Fabric Shrinkage during usage and processing is a challenge in the laundry and dry-cleaning industry. The fabric shrinkage might be a form of a decrease in the fabric's dimensions when in use. In many situations, it causes alteration along the sleeve or trouser length of garments, suits, or jackets. Thus, it is a source of dissatisfaction for the customers as well as textile care service providers. Many works of literature have shown that fabric shrinkage is a dimensional change in a fabric that results in a decrease in length, width, or even both. The degree of shrinkage varies from fiber to fiber. For instance, untreated 100% wool fabric without pretreatment with an anti-shrink agent tends to shrink severely. Fabric not only shrinks during the laundry process but to some extent while undergoing dry cleaning operations. Shrinkages are classified into different forms [1].

Types of Shrinkage in Fabric

- Relaxation Shrinkage
- Felting Shrinkage
- Swelling Shrinkage
- Contraction Shrinkage
- Progressive Shrinkage

• **Relaxation Shrinkage:** During Preparatory processes such as warping, winding, and weaving operations yarns are usually under tension. Thus, the fabric assumed a tension state instead of its actual dimensions. When finished textile fabric leaves the manufacturing mill, it is subjected to various applications. In the course of use by the consumer, the fabric may be subjected to cleaning processes such as laundry or dry-cleaning operations. Subsequently, the tension in the yarn is relaxed while in a wetting state, and a sudden dimensional change occurs. Therefore, it results in a reduction in length or width or both. This is referred to as relaxation shrinkage as it happens for the first time the material experiences a dimensional decrease after leaving a textile mill [1].

• **Felting Shrinkage:** Felting Shrinkage is peculiar to 100% wool or wool blend fabric due to its inherent characteristic. It had been reported that the microscopic examination of the wool fiber surface revealed a scaly structure and was responsible for directional friction among adjacent fibers. During mechanical agitation, the adjacent fibers move slightly and key into the scales of other fibers and resulting in dimensional reduction [2].

• **Swelling Shrinkage:** Swelling shrinkage is a situation in which fabric increases in dimensions due to water absorption. Subsequently, when desorption takes place, the original dimensions become obvious. This behavior affects shrinkage tendency significantly [1].

• **Contraction Shrinkage:** Fabric contraction occurred due to the high temperature encountered during washing, ironing, or drying in a tumbler drier. This shrinkage type is more prominent in synthetic fibers or fabrics than it is in natural fibers.

• **Progressive Shrinkage:** Progressive shrinkage is a persistent shrinkage in the clothing materials or fabric that happens every time an article undergoes laundry or dry-cleaning operation [2].

Essential Washing Factors or Washing Chemistry Variables

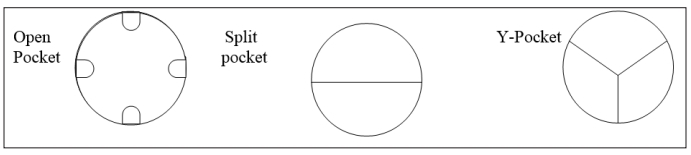
Quality and efficient cleaning of fabric or textile material is a product of balance among washing variables. The essential variables are in the acronym WATCH.

W- Water
A- Agitation (Mechanical Movement)
T- Time (washing cycle duration)
C- Concentration of Washing Chemicals
H- Heat energy that results in to change in the temperature of washing liquor [3].

However, these variables must work together to achieve optimum washing chemistry. For instance, when the water level increases, the time to reach the desired washing temperature also does. Similarly, a low water level requires low chemical concentration; high-level water needs high chemical concentration to attain washing solution concentration for the chemical to exercise its cleaning action. It is important to note that as these factors contribute to efficient washing, they also harm delicate fabrics such as wool or others. Untreated 100% wool fabric without anti-shrinking agents (such as chlorination that eliminates scales or envelopes the scale on the wool fiber by resin treatment), a significant shrinkage may be encountered.

In addition, machine programs and configuration contribute to the magnitude of shrinkage that occurs. A machine may have varying cylinder configurations and programs designed for different articles of textile fabric by manufacturers. In many instances, the claimed programs might not work for those fabrics. Therefore, it is important to understand how to manipulate the available manufacturers' variables to achieve optimum results during cleaning.

Furthermore, the wash-wheel cylinder configuration exists in an open pocket, split pocket, and Y-Pocket. Out of these configurations, an open pocket has the highest mechanical agitation follows by a split pocket and the Y-pocket is more flexible with the least mechanical action or agitation (it is recommended for delicate fabric such as wool).



Washing Machine Configurations

Methodology and Materials

The approach to this study is purely scientific experiments in which different six fabric pieces were subject to varying washing parameters at a constant washing load. The preloaded washer extractor was used to simulate washing action and gravitation forces exerted on fabric in a real washing situation. The washing machine variables under investigation include programs, spinning speeds, and temperatures at a constant chemical supply (only liquid detergent). The equipment and materials used are a stopwatch, meter rule, pieces of 100% wool, and a Washer Extractor (LG model F1068QDP2, washing capacity, 7kg of dry weight of fabric) [3].

Hand electric iron at wool setting – Fabric fiber composition: 100% wool

Procedure

Six pieces of 100% wool fabric were cut and their initial dimension was measured and recorded. They were later subjected to varying machine programs, temperatures, and spinning speeds. Their new dimensions were noted and recorded after ironing. The experiment was repeated for each washing variable while other variables remained constant. The area shrinkage was calculated for each variable under investigation.

Where

- Wi is the initial width of the fabric.
- Li is the initial length of the fabric.
- Ai is the initial area of the fabric.
- W1 is the new width of the fabric after washing.
- L1 is the new length of the fabric after washing.
- A1 is a new area of the fabric after washing.
- ∑Ai is a summation of the area before washing.
- ∑A1 is a summation of the new area after washing.

Table 1: Default Machine Program Parameters

S/N	Washing Program	Temperature (°C)	Spinning Speed
1	Cotton	60	1000
2	Cotton Quick	40	800
3	Synthetic	40	800
4	Delicate	40	800
5	Babycare	60	800
6	Handwash/ Wool	40	800
7	Blanket	40	800
8	Quick 30	30	800
9	Rinse & Spin	N/A	N/A

Table 2: Pieces of Wool Samples and their Initial Dimensions

Samples	Width (Cm) (Wi)	Length (cm) (Li)	Area (cm^2) (Ai)
A	6.9	10.8	74.52
B	5.8	10.5	60.90
C	8.1	12.0	97.20
D	8.3	10.4	86.32
E	6.8	7.0	47.60
F	5.2	7.8	40.56
Total			**∑Ai = 407.10**

Results

Table 3: Default Machine Programs New Dimension

Program	Cotton		Cotton Quick		Handwash Wool		Delicate		Quick 30º		Synthetic	
Sample (Cm)	Wi	Li	Wi	Li	Wi	Li	Wi	Li	Wi	Li	Wi	Li
A	6.8	10.4	6.7	10.3	6.7	10.3	6.7	10.2	6.6	10.1	6.7	10.2
B	5.7	10.5	5.7	10.5	5.7	10.5	5.5	10.6	5.6	10.4	5.6	10.6
C	7.9	11.9	7.9	11.9	7.9	11.8	7.8	11.8	7.7	11.7	7.8	11.7
D	8.2	10.4	8.2	10.4	8.2	10.4	8.2	10.4	8.1	10.4	8.2	10.4
E	6.7	6.9	6.7	6.9	6.7	6.9	6.7	6.9	6.7	6.8	6.7	6.8
F	5.2	7.9	5.2	7.8	7.8	5.1	5.2	7.9	5.1	7.8	5.1	7.8

Table 4: Areas of New Dimensions after Washing using Default Programs (cm^2)

Program	Cotton	Cotton Quick	Handwash/ Wool	Delicate	Quick 30º	Synthetic
A	70.72	69.01	69.01	68.34	66.66	68.34
B	59.85	59.85	59.85	58.30	58.24	59.36
C	94.01	94.01	93.22	92.04	90.09	91.26
D	85.28	85.28	85.28	85.28	84.24	85.28
E	46.23	46.23	46.23	46.23	45.56	45.56
F	41.08	40.56	39.78	41.08	39.78	39.78
Total	397.17	394.94	393.37	391.27	384.57	389.58

Table 5: Change in Fabric Areas (∑Ai - ∑A1) and Shrinkage in Different Programs

Program	Cotton	Cotton Quick	Handwash/ Wool	Delicate	Quick 30	Programs Synthetic
(∑Ai (Constant cm^2)	407.10	407.18	407.10	407.10	407.10	407.10
∑A1	397.17	394.94	393.37	391.27	384.57	389.58
(∑Ai- ∑A1) in cm^2	9.93	12.16	13.73	15.83	22.53	17.52
% Shrinkage	2.44	2.99	3.37	3.89	5.53	4.30

Note: $\boldsymbol{Percentage\ Area\ Shrinkage = \frac{\sum A_i - \sum A_1}{\sum A_i} \times 100\%}$

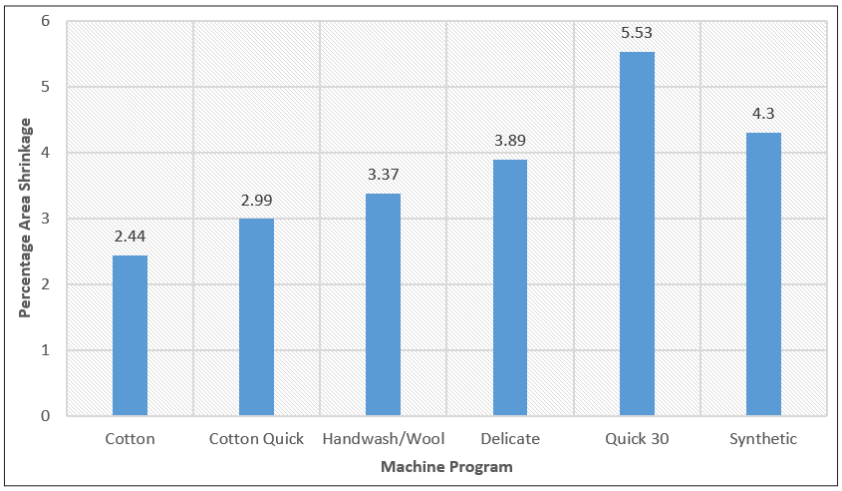


Figure 1: Bar Charts showing Percentage Shrinkage in 100% Wool against Washing Machine Default Program

Results of varying washing machine parameters. Variables under control are temperature, spinning speed, and washing programs.

Table 6: Washing Temperature

No. Spanning	Temperature (°C)						Area (cm^2) at Temp		
Sample (Cm)	CM (30)		CM (40)		CM (60)		30°C	40°C	60°C
	Wi	Li	Wi	Li	Wi	Li	Wi	Li	Wi
A	6.8	10.2	6.8	10.4	6.8	10.4	69.36	70.72	70.72
B	5.6	10.4	5.7	10.5	5.6	10.4	58.24	59.85	58.24
C	7.7	12.0	7.8	11.6	7.7	11.6	92.40	90.48	89.32
D	8.2	10.5	8.2	10.5	8.2	10.5	86.10	86.10	86.10
E	6.7	6.8	6.7	6.7	6.6	6.7	45.56	44.89	44.22
F	5.7	7.7	5.1	7.8	5.1	7.8	43.89	39.78	39.78
Total ($\sum A_i$)							395.55	388.82	388.38

Varying washing temperatures at the constant program (Cotton quick) and fixed spinning speed at zero spinning.

Table 7: Change in Areas at Varying Washing Temperatures and Percentage Area Shrinkage

Temperature	At 30°C	At 40°C	At 60°C
(Ai) Initial Area (cm^2)	407.10	407.10	407.10
(At) New Area (cm^2)	395.55	388.82	388.38
Change in Area ($\sum A_i$- $\sum A_t$)	11.55	18.28	18.72
% Shrinkage $\frac{\sum A_i - \sum A_i}{\sum A_i} \times 100\%$	**2.84**	**4.49**	**4.60**

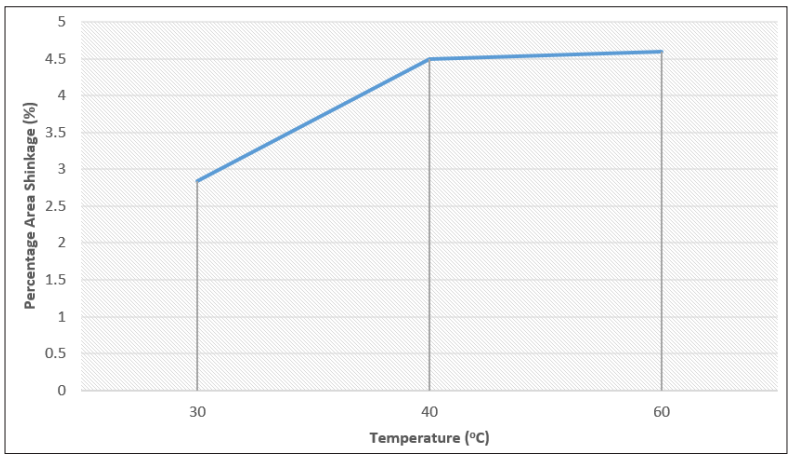


Figure 2: Graph Showing Percentage Shrinkage in Areas at Different Temperatures

Table 8: Changing in Spinning Speed at Constant Temperature (Room Temperature) and Fixed Machine Program

Sample (Cm)	Spinning Speed						Area (cm^2) at Spinning		
Sample (Cm)	400		800		1000		30°C	40°C	60°C
	Wi	Li	Wi	Li	Wi	Li	Wi	Li	Wi
A	6.7	10.2	6.8	10.3	6.9	10.4	68.34	70.04	71.76
B	5.5	10.7	5.6	10.7	5.7	10.8	58.85	59.92	61.56
C	7.8	11.9	7.8	11.9	8.0	12.0	92.82	92.82	96.00
D	8.1	10.2	8.1	10.2	8.2	10.3	82.62	82.62	84.46
E	6.8	6.9	6.8	6.9	6.8	7.0	46.92	46.92	47.60
F	5.7	7.8	5.1	7.8	7.8	39.78	39.78	39.78	39.78
Total ($\sum A_i$)							389.33	392.10	306.12

Table 9: Change in Areas at Varying Washing Spinning Speeds and Percentage Area Shrinkage

Spinning Speed	400	800	1000
(A_i) Initial Area (cm^2)	407.10	407.10	407.10
(A_t) New Area (cm^2)	389.33	392.10	306.12
Change in Area ($\sum A_i - \sum A_t$)	17.77	15.00	100.98
% Shrinkage $\frac{\sum A_i - \sum A_i}{\sum A_i} \times 100\%$	**4.37**	**3.69**	**24.81**

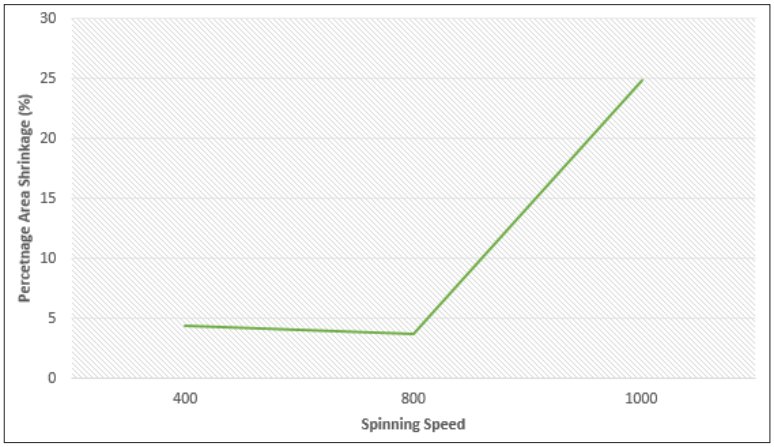


Figure 3: Graph Showing Percentage Shrinkage in Areas at Varying Washing Spinning Speeds

Table 10: Fabric Dimensions at Varying Machine Programs (Non-Default) and Constant Temperature (Room Temperature) and Spinning (No Spinning)

Machine Program	Cotton Quick		Handwash		Cotton		Quick 30		Delicate		Areas (cm^2)				
Sample	W1	L1	/Wool	L1	W1	L1	W1	L1	W1	L1	1	2	3	4	5
A	6.6	10.4	6.7	10.5	6.7	10.5	6.6	10.5	6.5	10.4	68.4	70.35	70.35	69.30	67.60
B	5.8	10.5	5.7	10.6	5.7	10.6	5.7	10.7	5.6	10.6	60.98	60.42	60.42	60.99	59.36
C	8.0	11.9	8.2	11.4	7.9	11.9	7.9	11.8	7.9	11.8	95.20	93.48	94.01	93.22	93.22
D	8.2	10.4	8.2	10.4	8.2	10.4	8.2	10.4	8.2	10.3	85.28	85.28	85.28	85.28	84.46
E	6.7	6.9	6.7	6.8	6.7	6.7	6.7	6.7	6.6	6.7	46.23	45.56	44.89	44.89	44.89
F	5.2	7.8	5.2	7.8	5.1	7.9	5.1	7.8	5.1	7.9	40.56	40.56	40.29	39.78	40.29
Total ∑A1											396.57	395.65	295.24	393.46	389.82

Table 11: Change in Areas at Varying Machine Programs at Room Temperature, No Spinning and Percentage Area Shrinkage

Program	Cotton Quick	Handwash/Wool	Cotton	Quick 30	Delicate
(A_i) Initial Area (cm^2)	407.10	407.10	407.10	407.10	407.10
(A_t) New Area (cm^2)	396.57	395.65	395.24	393.46	389.82
Change in Area ($\sum A_i - \sum A_t$)	10.53	11.45	11.86	13.64	17.28
% Shrinkage $\frac{\sum A_i - \sum A_p}{\sum A_i} \times 100\%$	2.59	2.81	2.91	3.35	4.24

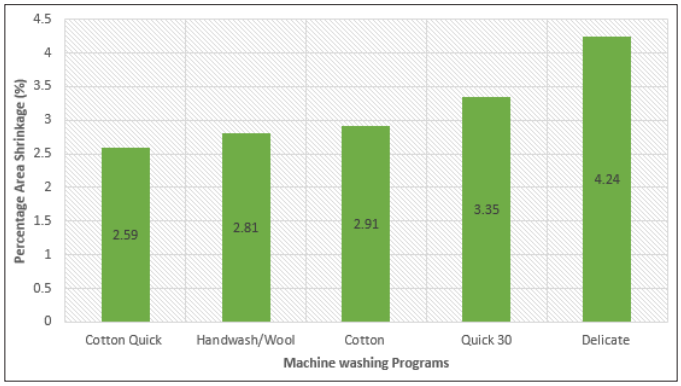


Figure 4: Bar Chart showing Area shrinkage at Constant Spinning Speed and Fixed Temperature for Different Machine Programs

Discussion of Findings

The bar charts in figure 1 show that the default machine program at Cotton indicates a least in area shrinkage of 100% wool fabric sample followed by Cotton Quick. The highest area shrinkage is in the program, Quick30, and next to it is the program labeled Synthetic. Also, the default program (Handwash/Wool) for wool articles does not prevent significant shrinkage as the cotton program does. The program, Delicate is in the third position to Cotton Quick in terms of the highest degree of shrinkage experienced.

In figure 2, the graph shows the effects of temperature area shrinkage when other variables remained constants. The trend line suggests a sharp increase in shrinkage as the temperature increases from 30 to 40°C. As the temperatures approach 60°C, there is a steady increase in area shrinkage from 40°C. There is no significant increase in shrinkage as the graph gradient tends to Zero-value from 40 to 60°C.

Figure 3 indicates shrinkage at varying washing spinning speeds. The graph shows that shrinkage is not directly proportional to an increase in spinning speed. The percentage area shrinkage slightly declines from the spinning speed of 400 to 800 spinning; this may be regarded as the optimum spinning range to have a minimum shrinkage value in the 100% wool fabric.

Figure 4 are bar charts indicating percentage areas of shrinkage of wool at manipulated machine-washing programs when temperature and spinning speed remain fixed. The program Delicate has the peak shrinkage and is followed by Quick 30. The Handwash/Wool and Cotton have a slight difference in their values while minimum fabric shrinkage was observed with the Cotton Quick program.

Conclusion

Based on the findings of the experiments, a washer-extractor with an open pocket configuration and default program for Handwash/Wool by the machine manufacturer does not prevent shrinkage in wool fabric. The program Quick 30 shows a more aggressive effect and mechanical action on wool shrinkage. Thus, the default program for washing wool fabric is unrealistic in shrinkage prevention. Also, an increase in temperature does not mean an increase in fabric shrinkage. At a point, the shrinkage does not progress as the temperature rises to 60°C. Below this temperature value, fabric shrinkage increases significantly. A lower spinning speed does not translate to lower fabric shrinkage. Therefore, spinning at 800 is the optimum value to minimize fabric shrinkage, provided that other variables such as temperature and the rest of the washing factors remained constant during washing cycles. A manipulation in washing programs variables, such as temperature and spinning (Washing factors), determines the degree of fabric shrinkage.

Lastly, the default program for washing wool fabric is not ideal for using an open-pocket washer extractor. Contrary to progressive shrinkage's perspective, the fabric cannot continuously shrink under all conditions, and as such washing factors such as temperature, spinning, time, and chemical and mechanical agitation determine the extent of shrinkage in wool fabric.

Recommendations

- More researches need to be conducted on the other brands of washing machines available in the markets as well as different configurations of wash wheel to verify manufacturers' claims.
- Other fabrics apart from wool as it was used in this study should be subjected to experiments using the same approach in the research.
- Future studies should focus on other washing factors that are not considered in this study.
- Textile care professionals in the textile care industry should avoid complete reliance on default programs when processing delicate fabrics.

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