An Examination of the Impact of Interfacing Fabric on Woolen Clothes Pilling Resistance

Nesreen Nasr Eldeen Hassan
Assistant Professor, Faculty of Applied Arts, Apparel Department, Helwan University, Egypt

Abstract:
Pilling is a serious problems in clothes, not only impairs its appearance but also reduces its service life. Pilling is a fabric surface fault in which ''pills'' of entangled fibers cling to the fabric surface that has long been recognized as a problem of wool fabrics. Several factors involved have been identified by some researchers. The purpose of this paper is trying to reduce the pilling of woolen fabric by using different types of interfacing fabric in different directions and layers in order to improve woolen fabric appearance and increase its service life.

In this study two different interfacing fabrics were used, one of them is woven interfacing fabric and the other is knit interfacing fabric. They adhesive to the basic fabric (100% wool fabric) in different directions (warp direction- weft direction and diagonal direction) after sewing the wool fabric by using superimposed seam and lock stitch 301. Pilling test was applied according to standards and took place into conditioned atmosphere of 21ºC and 65% RH. Comparisons have been made among the samples to investigate the impact of interfacing fabric on woolen clothes pilling resistance according to ASTM pill grade photographic views in a viewing cabinet after using 125 and 500 pilling cycles.

Keywords:
Wool fabric
Interfacing fabric
Purposes of interfacing
pilling.

Paper received 10th July 2016, Accepted 27th July 2016 , Published 1st of October 2016

Introduction
Fabric appearance is usually the highest priority consideration for consumers. Pilling is one of the most major factors which causes the fabric to have a worse appearance after a certain service period. [(1)] Pilling is undesirable property that affects handle and appearance of fabrics. [(2)] Fabric pilling is a serious problem for the apparel industry. Some researchers have investigated the mechanism of pill formation and the influence of fuzzing and pilling of wool since the mid-1950s. [(3)] Many textile scientists have studied the factors that generally affect pilling performance. Pilling attitude is prejudiced by not only the structure of the yarn and fabric but also by the fiber properties, e.g. tensile strength, percent elongation, flex abrasion, bending rigidity, fiber titer, shape of fiber cross-section and friction. As one of the results of fabric abrasion, the unsightly appearance of pilling can seriously compromise the fabric's acceptability for apparel. [(4)]

1.1. Wool fabric
Wool is a natural fiber composed of proteins, as it comes from the fleece of sheep. Over 200 varieties of fleece exist that are used for wool fabric production. [(5)] Sheep are generally sheared once a year, usually in the spring, and their hair is then sent to be graded and sorted. The grading system is based on the quality and length of the fleece. Each sheep has various grades of fleece found in their coat with the highest grade fibers being found on the sides, shoulders, and back, while the lowest grade are found on the lower legs. Once the wool has been graded, it is sorted so that similar grades are together and then sent to be cleaned and prepared for weaving. [(6)] After cleaning, the next step is to card the wool, which results in straight slivers of wool fibers. The shorter fibers are made into woolen yarns which may have ends lying in different directions, providing a twisted look. The longer fibers are made into worsted yarns, which are smoother and more uniform in appearance due to the tightly twisted nature of the fibers. [(7)]

Wool was the most commonly used fiber to make fabrics up until the industrial revolution, at which time it became simpler to mass produce other fabrics, such as cotton. Today, wool is viewed as a luxury fabric due to the high cost in manufacturing and maintaining it. Due to the fact that wool is a naturally occurring fiber, it has many unique properties that allowed for it to be one of the earliest fabrics used in the past and present. Wool crimps naturally, allowing the fibers to hold together and create a very strong yarn, but also creating air pockets that act as a natural layer of insulation and making it very desirable to wear in cooler weather. As a fiber, wool is also very strong and holds the original shape well. [(8)]

1.1.1. Advantages of wool fabric
• Extremely resilient when dry.

- Good drape (ability of fabric to fold while worn).
- Good elasticity (ability of fabric to increase in length and return to original dimension).
- Hydrophobic: absorbs water slowly, allowing the wearer to feel dry.
- Natural air pockets create a layer of insulation for warmth. (9)
- Great abrasion resistance.
- Provides bulk and loft to end products.
- Wrinkles easily fall out when exposed to humidity.
- Shapes well.
- Flame retardant (self-extinguishes when burned). (10)

1.1.2. Disadvantages of wool fabric

- Weak when wet, handle very gently.
- Dry cleaning is frequently the recommended method of cleaning.
- Can shrink up to half of its size if handled improperly.
- Dissolves in bleach or strong detergents (alkali).
- Becomes brittle if atmosphere is too dry.
- Some people may be allergic to wool.
- Articles made from worsted wool may irritate.
- Poor luster (reflection of light on fabric).
- Expensive.
- Pills (formation of tiny ball on surface of fabric). (11)

1.1.3. End uses of wool fabric

•Apparel: outerwear, sportswear, socks and suits. Woolen fabrics and yarns are traditionally made into bulky garments such as coats, heavy jackets and sweaters.

- Interiors: carpets, wall hangings (wool is the “look” against which synthetic carpets are measured).
- Industrial: felt pieces used in machines, used to clean up oil spills. (12)

1.2. Interfacing fabric

Many sewers, even the most advanced, consider interfacings a necessary evil. Interfacing is a critical ingredient in clothing construction. It can make the difference between a professional-looking garment and a disappointment. New developments in interfacing allow consumers to use these supportive fabrics successfully in a wide variety of fabrics and garment designs.

Interfacing is an inner construction material that lies between layers of fashion fabric. It adds shape, strength, and body. Almost every garment you make requires some type of interfacing for inner stability. Interfacing supports the fashion fabric and adds crispness, not bulk. It is used to reinforce areas that are subject to stress and helps a garment maintain its shape, wearing after wearing. Interfacing is also required for many home decorating items to add support and shape. (13)

The interfacing is usually a slightly lighter weight than the garment fabric. It should complement and reinforce the garment fabric without overpowering it. Place the garment fabric over the interfacing and feel them together to decide if the interfacing is heavy enough but not too stiff or heavy.

The interfacing should have the same care requirements as the garment fabric. It does not need to be identical in fiber content, but it should be washable. Hair canvas for fine tailored garments is the exception; it is dry cleanable only. The interfacing should have the same “give” or stretch as the garment fabric. Woven interfacing is generally used with a woven fabric, and knit or nonwoven interfacing with a knit to achieve the same “give”. Because interfacing has many purposes, you might use different kinds in different parts of a garment. For example, an interfacing with some “give” might be needed in a knit blazer as general interfacing, but a stable interfacing would be used in a buttonhole area. A dress might need crisp interfacing in the cuffs but something softer in the neckline. (14)

1.2.1. Purposes of Interfacing

The purpose of interfacing is to:

- stabilize fabric preventing stretching and sagging.
- customize seams.
- reinforce areas.
- support facings and/or garment details.
- stabilize necklines and waistbands.
- soften edges.
- give smooth, firm body.
- provide shape to areas such as shoulders, hems, collars and cuffs. (15)

1.2.2. Types of interfacing

There are a lot of interfacing fabrics on the market, there are only three basic types woven, nonwoven and knit. They can be sew-in or fusible. Woven and nonwoven are available in different weights. Each type of interfacing creates a different effect on the fabric.

Woven interfacings have lengthwise and crosswise grain. Woven interfacing is usually cut on the same grain as your fashion fabric. This enables the fashion fabric to maintain its natural drape and hand. If using woven interfacing in a knit fabric, cut the interfacing on the bias so the knit will maintain some of its basic “stretch” characteristics. Interfacings are mainly used on knits to stabilize and to prevent excess stretching.

Nonwoven interfacings are fiber webs. They are made by bonding or felting fibers together. These fabrics are flexible and do not ravel, wrinkle, or lose their shape. There are several types of nonwoven interfacings.

- **Stable** – has little "give" in any direction. They are excellent for shoulder pads and craft items.
- **Stretch** – has stretch crosswise, but is stable lengthwise. They are used in fashion fabrics to maintain the natural stretch.
- **All-bias** – has stretch in all directions. Usually there is more stretch in the crosswise. (15)

Knit interfacings are softer and more flexible because they stretch in all directions. They can usually be found in black, white, and neutral. Weft-insertions and warp-insertions are made on a knit machine, and then either a warp or weft yarn is inserted. The addition of the extra yarns makes this knit interfacing fabric more stable. These fabrics are softer than a woven interfacing. The weft insertion has the most stretch on the bias. The warp insertions have the most stretch in the crosswise direction, since the warp is inserted in a chevron design. They can be fused at a lower temperature than other fusible. (16)

1.2.3. Where to use interfacing

Interfacing is used anywhere it is important to add body, crispness, stability, durability, or strength. Interfacing strengthens and stabilizes areas where buttons, buttonholes, or other fasteners are sewn. It shapes and defines design features such as facings, necklines, collars, pocket flaps, cuffs, pockets, jacket hems, button and buttonhole areas, belts, waistbands, armholes, zipper areas and waistbands. It gives body to facings and necklines and stabilizes areas of strain. (17)

1.3. Pilling

Pilling on fabrics is a well-known phenomenon, which is defined as the entangling of fibers during washing, dry cleaning, testing, or wears to form balls or pills that stand proud of the surface of a fabric. During pilling, fibers become entangled and the different fibers around them join this structure, causing a more significant default on the fabric surface. As one of the results of fabric abrasion, the unsightly appearance of pilling can seriously compromise the fabric's acceptability for apparel. (18) Pills are formed in four stages: fuzz formation, entanglement, growth and wear-off. The yarn kind and fabric type are two of the most important parameters that affect pilling. The loose structure of yarn and fabric are effective on fuzz formation and more pill production. Pilling became an even more serious problem after the development and wide use of man-made fibers in textiles because fibers with delay the wear off stage higher tensile strength. (19)

Pilling is a fabric defect which is observed as small fiber balls or group consisting of intervened fibers that have been attached to the fabric surface by one or more fibers. Pilling in general, is a self-limiting process. (20) Subsequently, pills are broken off the fabric surface when by excessive frictions, the anchor fibers are broken. The pills are formed during wear and washing, which means that fabrics are affected by friction forces during usage. Friction forces results in the abrasion and pilling of fabric. Consequently there are some relationships between abrasion resistances and pilling .The construction of the fabric is also important in determining its susceptibility to pilling. A very tight, compact construction, such as denim, usually pills very little. However, a loosely knitted or woven fabric will show more pilling with both wear and cleaning. Pills do not interfere with the functionality of the textile, unless a spot with a lot of pills turns into a hole in the fabric. This is because both pills and holes are caused by the fabric wearing. (21)

The generation of the pill at the time of wearing wool fabrics mainly originates from properties of the raw material, the number of twist of the yarn, the fabric design, and others. But sometimes such a design is unwillingly employed because of aesthetic necessity and soft handle. The pilling phenomenon is largely developed when the yarn as the raw material is long and tough. The generation of the pill on the wool fabrics is also influenced by the post processing of dyeing and finishing. However, considerable challenge still remains to eliminate the pilling problem without adversely affecting other fabric properties, such as appearance and handle. (22)

1.3.1. Pilling is promoted by a number of factors

1- Pill formation rate-pill formation is a dynamic process in which pills are constantly formed and wear off. If the formation rate is greater than the break-off rate, then pills build-up on the surface.
2- The longer the staple length, the lower the pilling tendency, because there are fewer fiber ends protruding per unit area.
3- Coarser fibers are more rigid and hence they have a lower tendency to pill.
4- A circular cross section with smooth fiber surface allows the fiber to migrate to the surface of a fabric and form pills. Irregular cross sections reduce pilling.
5- Low tenacity fiber will increase pill wear-off rate. (23)

Traditionally fabric pilling evaluation is one of the most difficult works of textile quality measurement and control, the studies on this topic could be found in 1950,s until now, there are many international standards/methods developed for pilling evaluation. [24] However, most of them are subjective, and highly rely on subjective feeling and experiences of judges, so people attempt to develop objective evaluation methods instead of old ones. [25]

2. Experimental work

2.1. Fabric specifications

2.1.1. Basic fabric

100% Wool fabric was used and examined as a basic fabric. The following table1 illustrates the specifications of the basic tested fabric.

Table1 Basic fabric specifications

Fabric type	Fabric structure	Yarn warp/cm	Yarn weft/cm	Mass(gm/m^2)	Thickness(mm)
100% Wool fabric	Twill 2/2	20	18	380 $\pm$ 5	0.59

2.1.2. Interfacing fabric

Two different interfacing fabrics were examined, one of them is woven interfacing fabric and the other is knit interfacing fabric. The following table2 illustrates the specifications of the interfacing tested fabrics.

Table2 Interfacing fabrics specifications

Fabric type	Yarn warp-wales/cm	Yarn weft-courses /cm	Mass(gm/m^2)	Thickness(mm)
Woven interfacing fabric plain 1/1	13	14	85 $\pm$ 5	0.29
Knit interfacing fabric	8	12	64 $\pm$ 5	0.26

2.2. Sewing specifications

The wool fabric is sewed by using Mitsubishi sewing machine model LS2-1150 with speed 220 volt, 2850 cycles per min., and 5000 stitches per min. The following table3 illustrates the sewing specifications.

Table3 Sewing specifications

Seam type	Thread type	Thread size	Needle size	Stitch type	Stitch density/cm
Superimposed seam	100% spun polyester	Ne 42/2	16	Lock stitch 301	3

2.3. Adhesive proses specifications

The two different interfacing fabrics were adhesive to the basic fabric (wool fabric) beside the seam line in different directions (warp direction- weft direction and diagonal direction) in two cases

First: the woven interfacing fabric was adhesive to the basic fabric as a second layer in different directions and the knit interfacing fabric was adhesive to the fabric as a third layer in different directions too.

Second: the knit interfacing fabric was adhesive to the basic fabric as a second layer in different directions and the woven interfacing fabric was adhesive to the fabric as a third layer in different directions too.

The basic fabric was adhesive in the warp direction, all of the factors affecting the quality of the adhesive were installed when pasting the interfacing fabrics. The following table4 illustrates the specifications of the adhesive proses

Table4 Specifications of the adhesive proses

Press name	Press Type	Model no.	Working Area	Temp.	Power supply
Industrial press thermo adhesive I.P.T.	Manual	900	40 x 90 cm	150º	2250 Watt, 220 Volt

2.4. Pilling test

Tested samples examined after sewing and adhesive the two different interfacing fabrics in different directions to the wool fabric. The test was done by standard test method in conditioned atmosphere of 20ºC ± 2 and 65% ± 2 RH. Pilling test was carried out by using Martindale Tester M235 Instrument, according to ASTM: D 4970 – 02. [26]; average of three readings has been obtained for each property after using 125 & 500 pilling cycle.

3. Results and Discussion

3.1. Impact of woven interfacing when adhesive as a second layer and knit interfacing adhesive as a third layer on woolen fabric pilling resistance

3.1.1. Impact of woven interfacing when adhesive in warp direction

Table5, fig.1 illustrate the Pilling grades of wool fabric without interfacing

Table6, fig.2 illustrate the impact of woven interfacing when adhesive in warp direction

Table5 Pilling grades of wool fabric without interfacing

	Pilling Grades	
Sample	After 125 cycle	After 500 cycle
Wool fabric	2	1.5

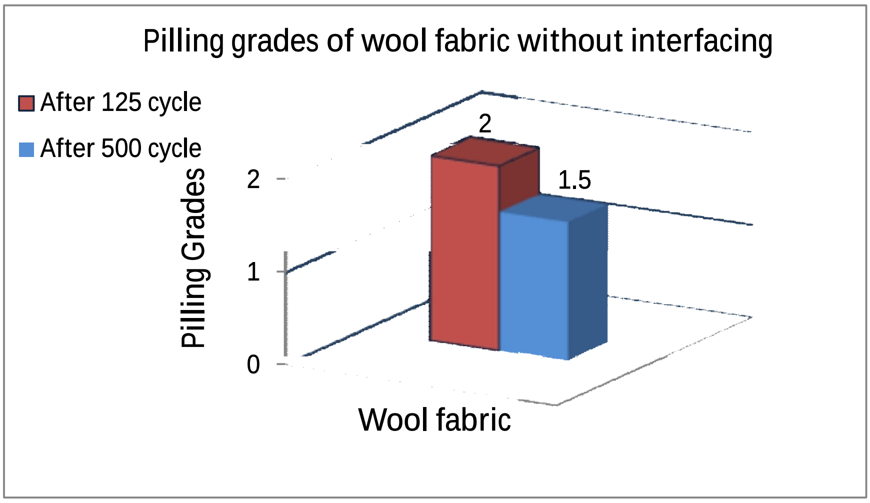

Fig.1. Pilling grades of wool fabric without interfacing

Table 6 Impact of woven interfacing when adhesive in warp direction

Sample No.	Pilling Grades	
	After 125 cycle	After 500 cycle
1 Woven interfacing (wa), Knit interfacing (wa)	2	1.5
2 Woven interfacing (wa), Knit interfacing (we)	2	1.5
3 Woven interfacing (wa), Knit interfacing (d)	2.5	2

***(wa):** warp direction ***(we):** weft direction ***(d):** diagonal direction

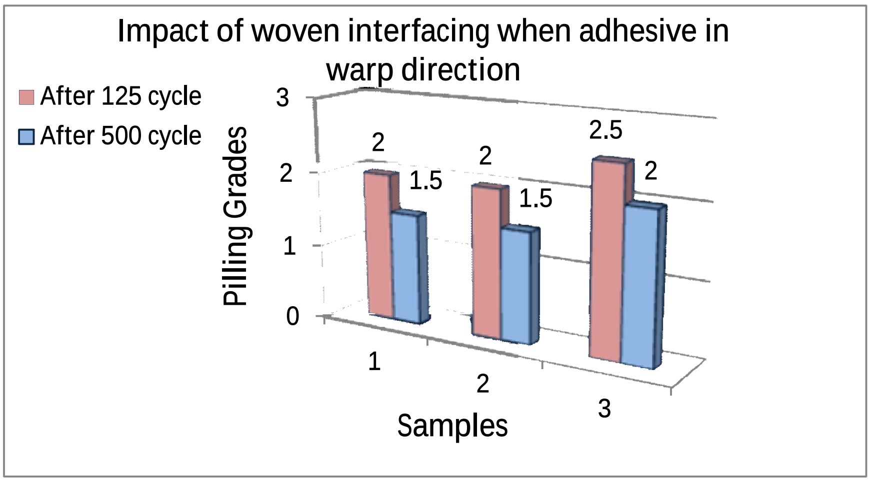

Fig.2. Impact of woven interfacing when adhesive in warp direction

3.1.2. Impact of woven interfacing when adhesive in weft direction

Table7, fig.3 illustrate the impact of woven interfacing when adhesive in weft direction

Table7 Impact of woven interfacing when adhesive in weft direction

Sample No.	Pilling Grades	
	After 125 cycle	After 500 cycle
4 Woven interfacing (we), Knit interfacing (wa)	2	1.5
5 Woven interfacing (we), Knit interfacing (we)	2.5	2
6 Woven interfacing (we), Knit interfacing (d)	2.5	2

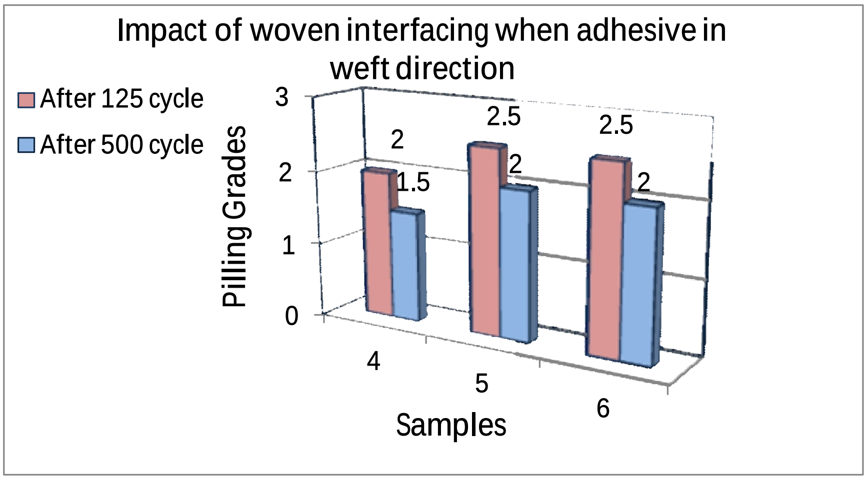

Fig.3. Impact of woven interfacing when adhesive in weft direction

3.1.3. Impact of woven interfacing when adhesive in diagonal direction

Table8, fig.4 illustrate the impact of woven interfacing when adhesive in diagonal direction

Table8 Impact of woven interfacing when adhesive in diagonal direction

Sample No.	Pilling Grades	
	After 125 cycle	After 500 cycle
7 Woven interfacing (d), Knit interfacing (wa)	2.5	2
8 Woven interfacing (d), Knit interfacing (we)	3	2.5
9 Woven interfacing (d), Knit interfacing (d)	3	2.5

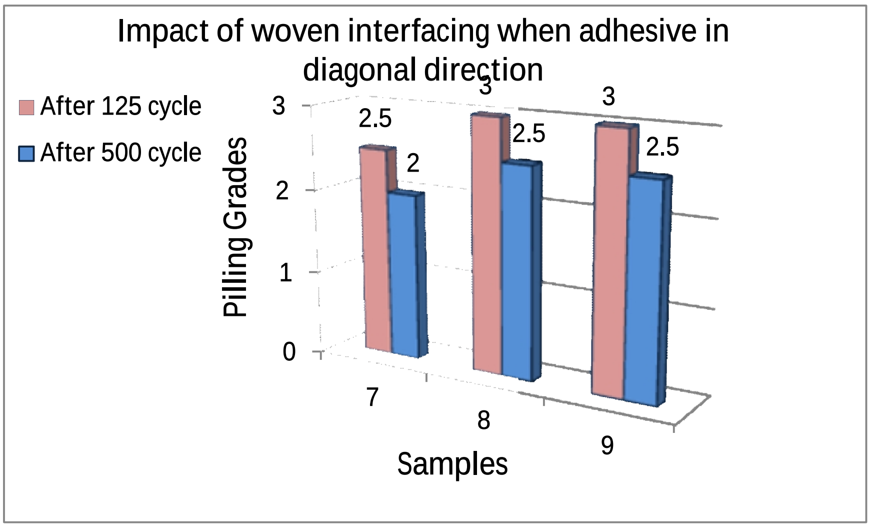

Fig.4. Impact of woven interfacing when adhesive in diagonal direction

- Pilling test specimens were evaluated by subjective comparison with standard picture of such specimens. This method is based on pill counts. Test specimens were evaluated by assigning to them a numerical rating of 1 to 5 which indicates their overall pilling in comparison with the standard. The average rating of each specimen reported by three evaluators.

5- No Pilling
4- Slight Pilling
3- Moderate Pilling
2- Severe Pilling
1- Very Severe Pilling

- As shown in table5, fig.1 which illustrate the pilling grades of wool fabric without interfacing it can be noticed that wool fabric without interfacing presents a worse pilling resistance after using 125& 500 pilling cycle.
- It can be noticed that pilling increases beside the seam line because it's a high area in the fabric, and decrease whenever far from the seam line. This is due to the increase of friction on the high areas of the fabric than the lower ones.
- As shown in tables6, 7& 8, figures.2, 3& 4 it can be noticed that adhesive the woven interfacing fabric to the basic fabric as a second layer in diagonal direction reduce the pilling and the wool fabric became more pilling resistance than adhesive the woven interfacing fabric to the basic fabric as a second layer in warp or weft directions after using 125& 500 pilling cycle. This is due to adhesive the woven interfacing fabric in diagonal direction makes the wool fabric more coherent, and work on the adhesion of free filaments (floating filaments) which located in the cloth and caused the fuzz, they do not fall in the structure of the thread, but be maintained from one end inside thread's diameter, and thus less the pilling and increased pilling resistance of the wool fabric.
- There is no difference in the results when adhesive the knit interfacing as a third layer of the fabric in the diagonal direction or in weft direction. Both are given the same result, but when adhesive the knit interfacing in warp direction it gives a worse result and presents a worse pilling resistance after using 125& 500 pilling cycle.

3.2. Impact of knit interfacing when adhesive as a second layer and the woven interfacing adhesive as a third layer on woolen fabric pilling resistance

3.2.1. Impact of knit interfacing when adhesive in warp direction

Table9, fig.5 illustrate the impact of knit interfacing when adhesive in warp direction

Table9 Impact of knit interfacing when adhesive in warp direction

Sample No.	Pilling Grades	
	After 125 cycle	After 500 cycle
10 Knit interfacing (wa), Woven interfacing (wa)	**2.5**	2
11 Knit interfacing (wa), Woven interfacing (we)	3	2.5
12 Knit interfacing (wa), Woven interfacing (d)	3	2.5

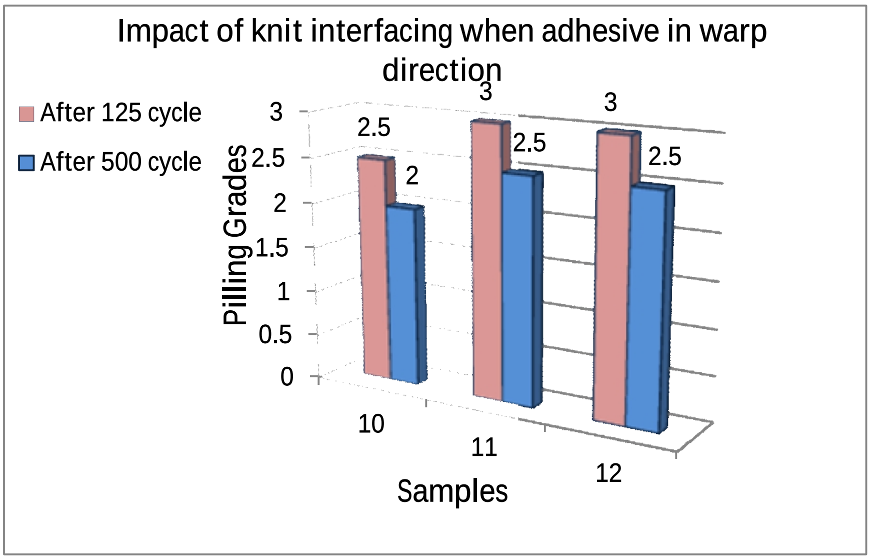

Fig.5. Impact of knit interfacing when adhesive in warp direction

3.2.2. Impact of knit interfacing when adhesive in weft direction

Table10, fig.6 illustrate the impact of knit interfacing when adhesive in weft direction

Table10 Impact of knit interfacing when adhesive in weft direction

Sample No.	Pilling Grades	
	After 125 cycle	After 500 cycle
13 Knit interfacing (we), Woven interfacing (wa)	3	2.5
14 Knit interfacing (we), Woven interfacing (we)	3.5	3
15 Knit interfacing (we), Woven interfacing (d)	3.5	3

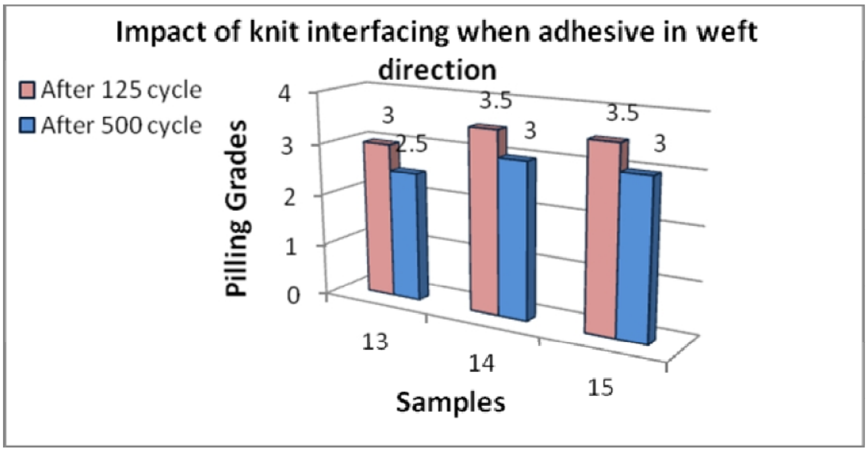

Fig.6. Impact of knit interfacing when adhesive in weft direction

3.2.3. Impact of knit interfacing when adhesive in diagonal direction

Table11, fig.7 illustrate the impact of knit interfacing when adhesive in diagonal direction

Table11 Impact of knit interfacing when adhesive in diagonal direction

Sample No.	Pilling Grades	
	After 125 cycle	After 500 cycle
16 Knit interfacing (d), Woven interfacing (wa)	3.5	3
17 Knit interfacing (d), Woven interfacing (we)	4	3.5
18 Knit interfacing (d), Woven interfacing (d)	4	3.5

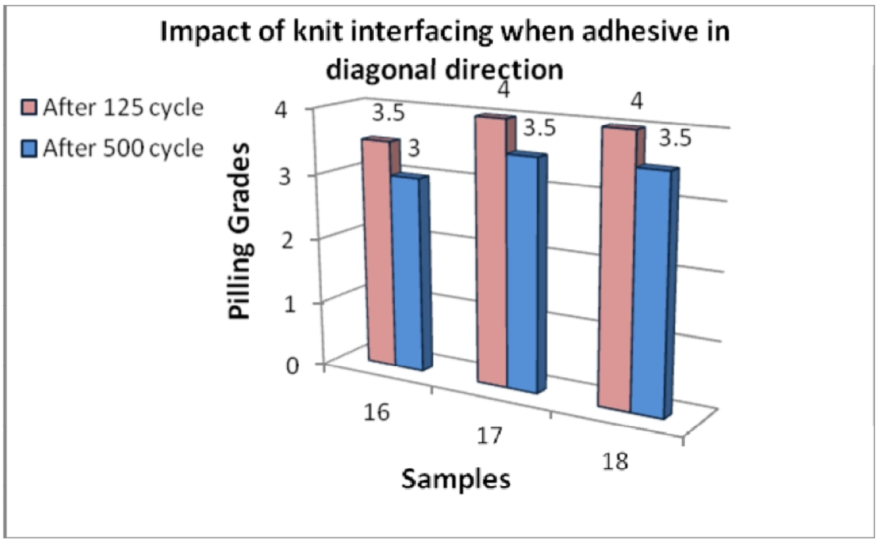

Fig.7. Impact of knit interfacing when adhesive in diagonal direction

- As shown in tables9, 10& 11, figures.5, 6& 7 it can be noticed that adhesive the knit interfacing fabric to the basic fabric as a second layer in diagonal direction reduce the pilling and the wool fabric became more pilling resistance than adhesive the knit interfacing fabric to the basic fabric as a second layer in warp or weft directions after using 125& 500 pilling cycle. This is due to adhesive the knit interfacing fabric in diagonal direction makes the wool fabric more coherent, and work on the adhesion of free filaments (floating filaments) which located in the cloth and caused the fuzz, they do not fall in the structure of the thread, but be maintained from one end inside thread's diameter, and thus less the pilling and increased pilling resistance of the wool fabric.

- It can be noticed that pilling increases beside the seam line because it's a high area in the fabric, and decrease whenever far from the seam line. This is due to the increase of friction on the high areas of the fabric than the lower ones.
- There is no difference in the results when adhesive the woven interfacing as a third layer of the fabric in the diagonal direction or in weft direction. Both are given the same result, but when adhesive the woven interfacing in warp direction it gives a worse result and presents a worse pilling resistance after using 125& 500 pilling cycle.
- Adhesive the interfacing fabric in the diagonal direction is presents a better pilling resistance of the wool fabric than adhesive the interfacing fabric in warp or in weft direction. This can be attributed to adhesive in diagonal direction makes the wool fabric more coherent, and work on the adhesion of free filaments, and thus less the pilling and increased pilling resistance of the wool fabric.
- It can be noticed that whenever the weight and thickness of the interfacing fabric is small whenever the adhesion to the outer fabric is better.
- Adhesive the knit interfacing fabric as a second layer of the fabric is presents a better pilling resistance of the wool fabric than adhesive the woven interfacing fabric as a second layer of the fabric. This can be attributed to the knit interfacing fabric which characterized by high susceptibility to adhesive on the surface of the outer fabric. It also has the properties of cohesion and stability and gives the outer fabric high flexibility and natural texture.

Conclusions

- Wool fabric is used in apparel for making outerwear, sportswear, socks and suits.
- Woolen fabric is forming a tiny ball on surface of fabric (pills) and it is one of the disadvantages of wool fabric.
- Interfacing fabric has a significant effect on pilling resistance of wool fabric.
- Types of interfacing fabric have a significant effect on pilling resistance of wool fabric.
- Knit interfacing fabric is presents a better pilling resistance of the wool fabric than woven interfacing fabric as a second layer of the fabric.
- The direction of adhesive the interfacing fabric has a significant effect on pilling resistance of wool fabric.
- Adhesive the interfacing fabric in the diagonal direction is presents a better pilling resistance of the wool fabric than adhesive the interfacing fabric in warp or in weft direction.
- The weight and thickness of the interfacing fabric have a significant effect on the adhesion of wool fabric, so whenever the weight and thickness of the interfacing fabric is small whenever the adhesion to the outer fabric is better.
- Pilling increases beside the seam line because it's a high area in the fabric, and decrease whenever far from the seam line.
- The author recommend using knit interfacing fabric as a second layer of wool fabric in the diagonal direction and woven interfacing fabric as a third layer of the wool fabric in the diagonal direction too in places that are exposed to severe friction such as the bottom of the armpit, elbow , neck area and so on.

References

1. Ouyang, W. “Evaluating Fabric Pilling/Wrinkling Appearance Using 3D Images”, M. SC. Thesis, University of Texas at Austin, 2013 .
2. Abdel–Fattah, S. H., and El-Katib, E. M. “Improvement of Pilling Properties of Polyester/wool Blended Fabrics”, Journal of Applied Sciences Research, Vol. 3(10): 1206-1209, 2007 .
3. An, A., Yu, W., and Jiang, G. “Pilling properties of wool single jersey made of compact and conventional ring yarns after anti-felting treatment”, Textile Research Journal, Vol. 84(7): 673–683, 2014 .
4. Amin, Md. R., and Rana, Md. I. “Analysis of Pilling Performance of Different Fabric Structures with Respect to Yarn Count and Pick Density”, University of Oradea, Romania, 2004 .

5. Hearle, J. W. “A critical review of the structural mechanics of wool and hair fibers”, Int. J. Biol. Macromol., Vol. 27(2): 123–138, 2000 .
6. Kadolph, S. J., and Langford, A. L. “Textiles”, 9th edit., Upper Saddle River: Prentice-Hall, 2001.
7. Johnson, N. A. G., and Russell, I. M. “Advances in wool technology", Woodhead Publishing Limited, England, 2009 .
8. Lapeer, C. “The Effects of Different Fabric Types and Seam Designs on the Seams Efficiency”, A Senior Thesis, Eastern Michigan University, Ypsilanti, Michigan, 2006.
9. Black, K., and Hatch, S. “From Fiber to Fabric: Wool”, FC/Clothing and Textiles Journal, 29pr, 2012.
10. Http:// www.americanwool.com, “Characteristics of Wool”, 6/2016.
11. Cohen, A. C., and Johnson, I. “J.j. pizzuto's fabric science”, 9th edit., Fairchild Books, New York 2010.
12. Liddell, L. A., and Samuels, C. S. “Apparel: Design, textiles & construction”, 10th edit., Goodheart-Wilcox, Tinley Park, IL, 2012 .
13. Speece, J. “Menswear-Front & Back Interfacing for Jackets”, Historical Materials from University of Nebraska, Lincoln Extension, 2000.
14. Lai, S. S. “Optimal Combinations of Face and Fusible Interlining Fabrics”, International Journal of Clothing Science and Technology, Vol. 13, NO.5, 2001.
15. Hackler, N. “Interfacing”, Institute of Food & Agriculture Sciences, University of Florida, Gainesville, FL, 2006.
16. Ruddy, K. “All about Interfacing”, www.uniquepatterns.com, 2016.
17. Stryker, M. “Selecting and using Interfacing”, Clothing and Textiles Journal, Cooperative Extension Service, Kansas State University, Manhattan, 2001.
18. Huang, H. “An Examination of the Possible Influence of Yarn Friction on Knitted Fabric Pilling Resistance”, M. SC. Thesis, Textile Engineering, Faculty of North Carolina State University, 2014.
19. Doustaneh, A. H., Mahmoudian, Sh., Mohammadian, M., and Jahangir, A. “The Effects of Weave Structure and Yarn Fiber Specification on Pilling of Woven Fabrics”, World Applied Sciences Journal, Vol. 24 (4): 503-506, 2013.
20. Li, L., Jia, G., and Zhou, W. “Effect of Yarn Properties on the Pilling of Cashmere Knitted Fabric”, Fibers & Textiles in Eastern Europe, Vol. 17, No. 6 (77), 2009.
21. Mori, M., Fujiumoto, T. and Murakami, M. “Influence of Fiber’s Surface Morphology Change on Anti-pilling Performance of Woolen Knitted Fabric”, International Conference on Kansei Engineering and Emotion Research, 2014.
22. Wan, A., Dai, X. J., Magniez, K., Plessis, J., Yu, W., and Wang, X. “Reducing the pilling propensity of wool knits with a three-step plasma treatment”, Textile Research Journal, Vol. 83(19) 2051–2059, 2013.
23. Bagherzadeh, A. S. “Abrasion and Pilling Resistance of Nonwoven Fabrics Made from Bicomponent Fibers”, M. SC. Thesis, Faculty of North Carolina State University, 2007.
24. Xin, B. “Characterization of Fabric Appearance Based on Image Analysis”, Ph.D. Thesis, Institute of Textiles and Clothing, Hong Kong Polytechnic University, 2009.
25. Zhang, J. and Wang, X. “Objective Pilling Evaluation of Wool Fabrics”, Textile Research Journal, Vol. 77(12): 929–936, 2007.
26. ASTM: D 4970 – 02: Method for determination of Pilling Resistance and Other Related Surface Changes of Textile Fabrics.