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# Study the dimensional behavior of knitted panels prepared from wool and acrylic yarn on fully fashion flat knitting machine

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## Abstract

The purpose of this research was to study the dimensional behavior of fully fashion flat knitting machine panels prepared on different knitting parameters. 32/2 Ne Wool and acrylic yarns were used. From the results it has been concluded that pre-knitting tension on yarn effects the dimensions of knitted panels after relaxing, washing and steaming. Medium (four-point) pre knitting tension on yarn with tight stitch length produced more dimensional stable structure than looser or medium stitch length. The structure with tight stitch length and medium pre-knitting tension resisted the shrinkage more after relaxing, washing and steaming process. Tensile results of acrylic yarn showed more strength than wool yarn and also having more percentage of elongation than wool. By comparison it is concluded that wool flat knitting panels showed more resistance towards shrinkage than acrylic panels prepared on same knitting parameters. Air permeability results of wool and acrylic panels showed that pre-knitting tension did not affect the air permeability values, but by changing stitch length air permeability of knitted panels changed.

**Keywords:**Dimensional behavior, V-bed flat knitting machine, 3D shape knitted panels, Air permeability, Single jersey, Knitted panels.



## 1. Introduction:

Clothing play an important role in the history of human. With the advancement of technology in the field of knitting improves the quality and quantity of knitted fabric. Natural, regenerated, synthetic as well as high performance yarns are now used to meet the world clothing demands.

Knitted fabric is popular due to its less rigid structure than woven and it is also preferable for its comfort properties. As knitted structure consists on loops and lot of spaces present between these loops, these spaces made knitted fabric dimensionally unstable. Due to presence of loops, the deformation occurs by applying low stress in the direction of width as well as in length. The stretch ability is considered as good property for comfort and sportswear garments. By using different types of knit stitches in fabric, the stretch ability can be increased or decreased in both directions. Usually fine gauge knitted fabric is used for summer garments and coarser gauge prefer for winter clothing. Different knitted structures have greater influence on dimensional stability of knitted fabrics. By increasing tuck stitches in single jersey fabric, the length wise shrinkage reduces and width wise shrinkage increases[1].Weft knitting divided into circular and flat knitting categories, that are able to produce single jersey, double jersey, collars, fleece, shaped and fully fashion garments. Usually v bed flat knitting machine is used to produce three dimensional shaped garments. V-bed knitting procedure is more advanced, and has different needle selection capability as compared to circular knitting. Using computerized flatbed knitting machines, various knitting patterns and knitting structures can be created. The body size shapes can be efficiently changed using a computer-aided simulation system[2]. In Fully-fashion knitting machine different parts of garments can be shaped through widening or narrowing knitting operation during its formation on machine. In loop transfer process knitted loops are transferred from machine front bed needles to rear bed needles. The widening and narrowing of shaped panels is also performed through loop transfer mechanism. This process allows the separate formation of shaped front, back panels and sleeves of garment by manipulating the number of loops. if, all parts of garment knitted discrete, the fully-fashioned knitting still requires a post sewing or linking process [3].

The shrinkage of shaped knitted garment depends on the parameters that are used during knitting production. It specially includes stitch length, pre knitting tension on yarn, take down tension and also on a properties of yarn that is used to produce fabric. After formation of knitted panel on machine, it's very difficult to measure its dimensions without relaxing it. Specially in single jersey fabric the more chances of dimension error, because the fabric is very sensitive to knitting stresses and it start curling from edges after take down [4]. Usually after relaxation of knitted fabric, reduction is noted in density of course and wale due to reduction in loop length, as loop length reduces the fabric become stiffer that affect the comfort properties in some cases [5]. The yarn linear density and stitch length did not change on repeated laundering except rear case. So, dimensional changes during washing is due to change in loop shape rather than shrinkage of loop. It is observed that most dimensional changing occurred after drying process[6].

According to research conducted by Mihai and Mirela, they prepared 3D knitted and intarsiaknitted samples on v-bed Stoll flat knitting machine. They described that no additional cost or attachment is required to produce 3D structure. They concluded that 3D knitting structure manufacturing process was simplified and having low manufacturing cost [7]. Yanxue Ma and Lamar, they studied 3D shaping on fully fashion v-bed flat knitting machine. According to their study more stable structures can be produce with three dimensional shaping flat knitting machines. And 3D shaping also increase the durability of knitted structure, that can be used for technical purpose[8].

This research work is based on fully fashion v bed flat knitting machine front knitting panels. The author has checked its dimensional changing after relaxed state, washing and steaming process. And also studied pre knitting yarn tension effect on air permeability values knitted panels.

## 2. Objective:

i. The main objective of this research was to study the dimensional behaviour of wool and acrylic fully fashion 3D knitting panel after knitting, home laundering and steaming process.
ii. The second objective of my research was to find out knitting parameters, that help the knitting panels to resist shrinkage most.
iii. And we have also studied the wool/acrylic yarn tensile and elongation properties.

## 3. Materials and method

Plain single jersey samples were prepared with wool and acrylic yarn. Both yarns were of same type and count of 32/2, purchased from local yarn market. As we know, wool is a natural fiber that grows on skin of sheep and composed of protein known as keratin. Wool contains carbon, nitrogen, hydrogen and sulfur. The structure of wool has crimp and hollow spaces inside it, that provide spongy feel (air also traps inside the hollow spaces and creates an insulation that gives feeling of warmth to the wearer). Its fiber structure consists of overlapped serrated scales that help the fiber. Because of this reason it absorbent and does not wrinkle easily. Wool also shows good resistance to acids but get damage by alkalis. It has excellent elasticity and resilience [9]. The acrylic fiber is a synthetic fiber made from the extrusion of a polymer known as poly-acrylonitrile. It is also known as synthetic wool due to its aesthetic properties, that are similar to natural wool. It is cost effective and extensively used in knitted garments. Similarly, in comparison to wool fiber it has good resistance to acid but less resistance to alkalis. Acrylic elastic recovery is poorer than wool [10].

Knitted panels were prepared with these above mentioned yarns on flat bed knitting machine. Fully fashioned v-flat bed machine of model SES122-S by Shima-seiki was used.This machine has parts like compound needle and racking mechanism, which allow the machine to transfer stitches for narrowing, widening and shaping of garment during knitting operation. Machines have extra yarn carriers for intarsia knitting and yarn tensioning devices which help the carriage for smooth operation.It is also equipped with special moveable sinkers over the needles which prevent the old stitches from being lifted as needle raises to clear the old loops.

Knitted panels of different shapes were prepared on CAD simulation system, that has capability to simulate the provided data easily. After successful feeding of knitting parameters, the first sample was knitted according to

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our requirement. This machine worked with SDS-ONE knit design system, that comes under digital knitting category. SDS-ONE knit design system is the “all-in-one” apparel design system that converts the designer’s concepts into virtual sample. SDS-ONE also help to communicate in different languages. By using this system, a designer can easily share its problem or information with other language people and make his work more efficient. This research has focused on subsystems involved in textile design, fashion design and prototype production through CAD. Knitted garments of different shapes can be created with different colors, stitches, structures and by using various types of textured yarns. Because it work on color codes, so SDS-ONE system automatically converts these color codes into machine language of Shima-seiki[11]. Models like super micro SDS a-52 has a user friendly interface allowing all stages, from planning, modelling, design, evaluation to 3d loop simulation of stitch architecture. It has a capability to handle large programming files. All knit programming and machine control data is based on colour numbers. This program has functions to create virtual image of different textured yarns (e.g. slub, marl, snarl, and boucle) and also estimate suitable yarn count according to machine gauge. With the advance function, the yarn color and twist can also be managed on machine.After pattern creation, the loop simulation converts it into a virtual model of sample as shown in figure-1. After conformation this design simulation can be fed into machine programming data. The input data can also be provided through removable discs. These machines require some manual setting like speed, pre-knit tension and number of design repeats.

**Figure 1: Simulated shaping pattern**



Shaping is the process of making curves in garments panels for sleeves and neckline during the knitting process through loop transfer mechanism. Figure-2 given below shows proper shaping mechanism with loop transfer and color diagram.

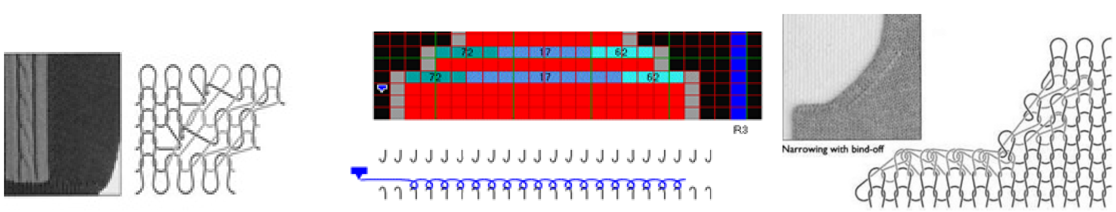


**Figure 2: Shaping during curve formation**

Total five knitting panels (A1, A2, A3, A4, and A5) of acrylic yarn were prepared with normal, tight and medium loop length. Similarly, two, four and six-point pre-knitting tension was selected for sample preparation. This research was focused on four point pre knitting tension, because more loose (six-point) and tight (two-point) pre knitting tension causes problem during knitting. In knitting medium (four-point) pre-knit tension is majorly used. For comparison the behaviour of two-point and six-point knitting tension, the knitting panels were also prepared. Similarly, five samples of wool (w1, w2, w3, w4, and w5) were knitted with same parameters that were used for acrylic sample preparation. The design of experiment for this study is given in below table.

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All tests for this research study were performed under ISO and ASTM Standards. The following table contain standard test methods:

Table 1: Design of experiment table

| Yarn | Fabric Type | Yarn tensioner | Sample Name | Stitch length marking |
|---|---|---|---|---|
| **Acrylic** | Fully fashioned knitting front panel | 4-points on machine (Medium) | A- 1 | Medium |
| | | | A- 2 | Tight |
| | | | A- 3 | Loose |
| **Acrylic** | Fully fashioned knitting front panel | 6-point on machine (High) | A- 4 | Medium |
| **Acrylic** | Fully fashioned knitting front panel | 2-point on machine (Low) | A- 5 | Medium |
| **Wool** | Fully fashioned knitting front panel | 4-points on machine (Medium) | W- 1 | Medium |
| | | | W- 2 | Tight |
| | | | W- 3 | Loose |
| **Wool** | Fully fashioned knitting front panel | 6-point on machine (High) | W- 4 | Medium |
| **Wool** | Fully fashioned knitting front panel | 2-point on machine (Low) | W- 5 | Medium |

**Table 2 ASTM**

| Name of test | Standard ASTM |
|---|---|
| **Width of knitted panels** | D3774 |
| **Mass per unit area** | D3776 |
| **Yarn Count** | D1059 |
| **Yarn tensile and extension** | ISO 13934-1:2013 |
| **Air permeability** | ISO 9237:1995 |
| **Dimensional Stability to washing** | AATCC 135 |

## 4. Results and discussion:

### 4.1 Tensile strength and elongation:

Tensile strength along with elongation of yarn can easily be calculated by using UTM machine. When a force is applied to a textile material, it stretches to certain length and its elongation is represented in terms of percentage.

Total five yarn samples of acrylic yarn were tested on UTM. Similarly, the wool yarn was tested on machine and its bar chart is in below figure-9. Wool yarn exhibited 25 to 35 % elongation at break under laboratory conditions. Acrylic yarn elongation at break is 20 to 50 %. It has been seen through comparison between wool and acrylic yarn, that the acrylic yarn has high elongation but its tensile strength was less. And wool yarn whose elongation was less with high tensile strength. Tensile strength and elongation of yarn will defiantly change after washing [12].

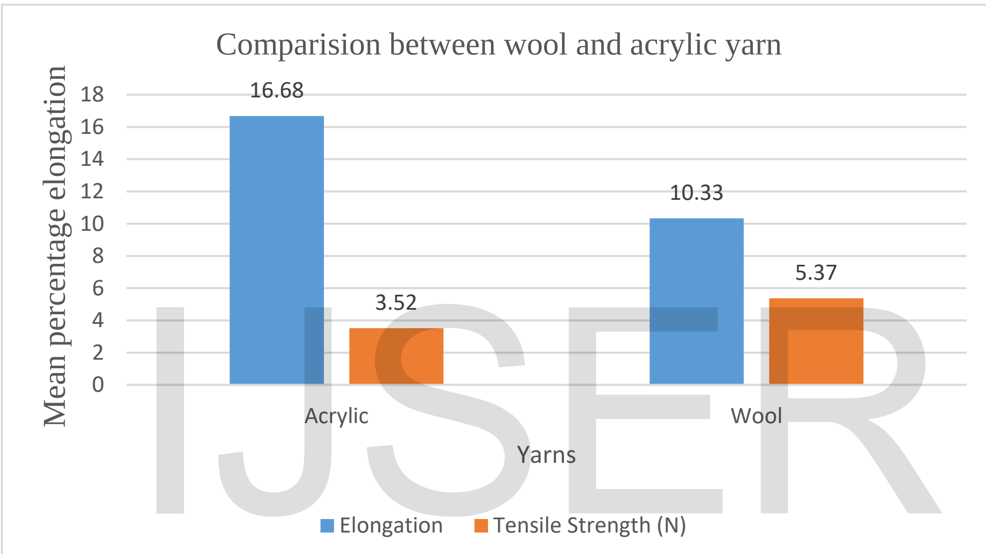


**Figure 3: Comparison between wool and acrylic yarn tensile strength and elongation**

### 4.2 Air permeability:

Air permeability measures the passage of air from fabric. Its value depends on structural configuration of fabric and on morphology of yarn. Wool and acrylic knitted panels values showed in tables-8/9 along with their standard deviation values. Knitted panels was tested on one hundred Pascal pressure. Table-8 showed the values of wool panels samples that were knitted under four, six and two point pre knitting yarn tension. The first three samples were knitted on same pre knitting tension but having tight, medium and loose stitch length as describe in design of experiment table-3. The W-4 and W-5 panels were knitted on same (medium) stitch length but with different pre knitting yarn tension as described in a design of experiment table. The Air permeability of w-4 and w-5 was almost same, so it showed that the influence of pre -knitting yarn tension on air permeability values was negligible. And air permeability of w-1, w-2 and w-3 showed that, as we increased stitch length the more air can flow from fabric as shown in table-8 [13].

The wool and acrylic panels values were different from each other; this behaviour was due to morphology of yarn. The acrylic panels air permeability values shown in table-9 were very less from wool panels; this was due to after wash behaviour of acrylic yarn. The bar chart in figure-11 explains the acrylic panels A.P values with standard deviation. In knitted loops acrylic yarn usually covered more space between loops after washing because it has more relaxing behaviour than wool.Standard deviation values of wool were more than acrylic yarn, as values given in below table-8.

### 4.2.1 Wool air permeability Values and their standard deviations

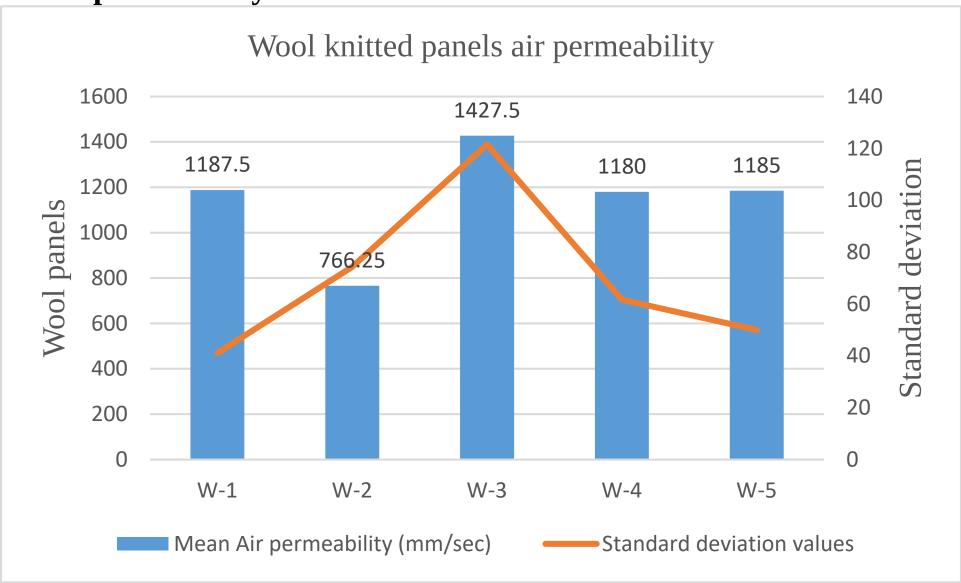


**Figure 4: Air permeability values of wool knitted panels**

### 4.2.2 Acrylic air permeability values with their standard deviations

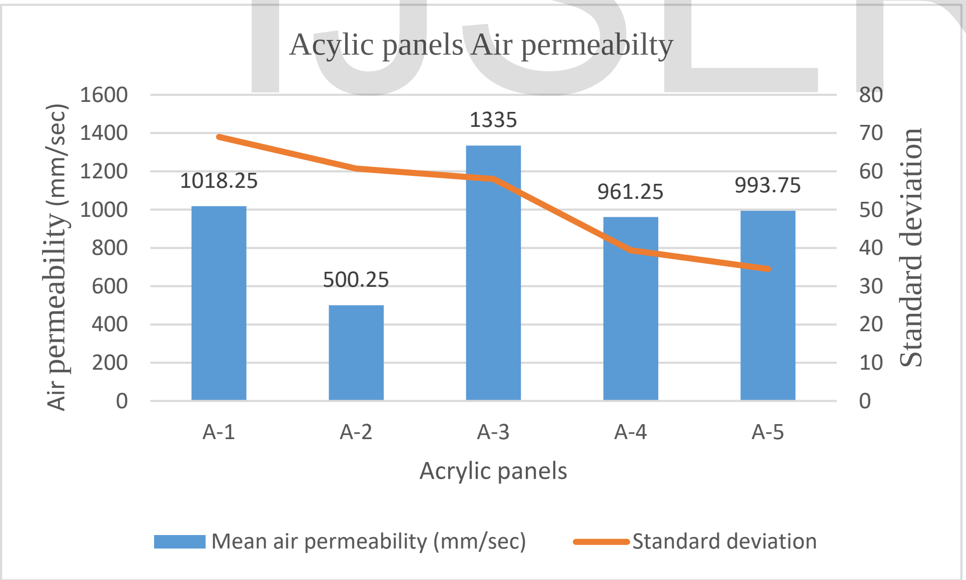


**Figure 5: Air permeability values of acrylic yarn**

## Gsm Calculation:

Gsm of fully fashioned knitted panels calculated under a standard test method D3776. All wool and acrylic samples gsm is given in a below table.

**Table 3 GSM**

| Samples | Tension | Loop length | GSM |
|---|---|---|---|
| **W-1** | Normal(4points) | Medium | 332 |
| **W-2** | Normal(4points) | Tight | 340 |
| **W-3** | Normal(4points) | Loose | 323 |
| **W-4** | High(6points) | Medium | 395 |
| **W-5** | Low(2points) | Medium | 312 |
| **A-1** | Normal(4points) | Medium | 340 |
| **A-2** | Normal(4points) | Tight | 346 |
| **A-3** | Normal(4points) | Loose | 329 |
| **A-4** | High(6points) | Medium | 407 |
| **A-5** | Low(2points) | Medium | 320 |



### 4.3 Dimensional Stability results:

Total two washes applied under ASTM standard mentioned in table-4, the Wash cycle was normal with wash load 1800gms. After washing samples were dried under normal condition.

Wool and acrylic panels results after washing mentioned in a table-10 below. Their dimensional comparison after knitting, washing and steaming showed in table-11. From results it is concluded that the fully fashioned knitted panels dimensions were extremely unstable. The shrinkage values of wool and acrylic panels changed by changing pre knitting yarn tension as well as stitch length. And result showed that the wool and acrylic knitted panels dimensions were different on same knitting parameters. The shrinkage resistance of wool and acrylic flat knitted panels majorly depends on raw material, stitch length and pre knitting yarn tension. Panels dimensional values were changed by changing stitch length and minor effect of yarn pre knitting tension values also observed on knitted panels.

As mentioned in the previous chapter, totally ten flat knitting panels were prepared from wool and acrylic yarn with three loop length and yarn pre knitting yarn tension values.

**Table 4: Shrinkage % values of knitted panels**

| Sample Description | Shrinkage % | |
|---|---|---|
| | **Wales** | **Courses** |
| **W-1** | -7.96 | -3.98 |
| **W-2** | -1.49 | -1.49 |
| **W-3** | -2.48 | -1.99 |
| **W-4** | -10.45 | 14.43 |
| **W-5** | -9.45 | 9.45 |
| **A-1** | -4.47 | 7.96 |
| **A-2** | -3.98 | 8.45 |

| | | |
|---|---|---|
| **A-3** | -10.45 | 14.43 |
| **A-4** | -10.45 | 13.43 |
| **A-5** | -6.96 | 12.94 |

The yarn count was 32/2 Ne and its tensile testing and mean percentage elongation checked with UTM. Universal testing machine results showed that acrylic yarn having less tensile strength than wool. The prepared samples from wool and acrylic undergoes air permeability and home laundering standard testing as well. The air permeability results showed that, as we increased loop length the mean values of air permeability increases. W-3 panel with loose loop length shows very less resistance to dimensional stability and similar behaviour noted with A-3 panel having same parameters. The first three samples were prepared on four-point controlled pre knitting tension. W-1 knitted panels shrinkage behaviour was out of limit due to medium stitch length. The w-2 and w-3 panels were most shrinkage resistant panels with medium and tight stitch length respectively. By losing pre knitting tension the panels shrinkage gone out of range and w-4 and w-5 were examples of these types knitting panels. Felting shrinkage is more prominent in wool yarn due to its scaly surface. Actually when wool wet under mechanical load it shrinks and after shrinkage the scale on surface more closely packed, this was the main reason behind the negative values of wool
knitting panels shrinkage.

The acrylic panels showed almost totally different nature than wool knitting panels. A-1 and A-2 samples were less shrinkage resistant than wool W-1 and W-2, this was due to less resistant behaviour of acrylic against shrinkage. Similarly, the panels named as A-3, A-4 and A-5 also less resist to the shrinkage. The acrylic yarn has very poor elongation that's why its shrinkage was positive [14]. In a course wise direction of acrylic panels showed extension, that was out of acceptable limit of shrinkage.

## 5. Conclusion:

From research it is concluded that, on same knitting parameters wool and acrylic panels showed different dimensional behaviour. Knitted panels have different dimensions after relaxing, washing and steaming. Wool panels resisted better to shrinkage than acrylic panels. It has been observed that by increasing pre knitting tension on yarn, the length of single jersey panels decreases. The most stable structure has found with tight loop length and on four-point pre knitting tension, so wool panel shrinkage was under ± 5% limit. Acrylic panel with tight stitch length and four-point pre-knitting tension shrinkage was near to allowed limit. The comparison between wool and acrylic yarn showed that acrylic have high elongation but its tensile strength was less comparatively to wool yarn whose elongation less with high tensile strength. As stitch length increases the values of air permeability was also increased. Air permeability values comparison showed that acrylic panels have less passage for air than wool. And pre knitting tension values on yarn did not affect the air permeability values.

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