Exploring weft knit fabric defects based on their presence and quality impact: A case study

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ABSTRACT

While addressing grey fabric quality in a renowned circular weft knitting mill of Bangladesh, the authors experienced some questionable approach practiced by knitters. The subjective nature of defect detection by knitters/inspectors often causes wrong emphasizing on frequently occurring defect(s) instead of focusing on influential defect(s) and subsequently, employing wrong quality control approach to minimize the grey fabric defects. Knit fabric defects should be assessed by type, fault coverage, gravity and the frequency of occurrence instead of focusing only on frequency of occurrence in the fabric. In this study, grey weft-knitted fabric quality is investigated influential defects based on how these defects influenced fabric roll acceptance and rejection decision. Quality data of single jersey, fleece and 1X1 rib were gathered and analyzed from an established knitting factory in Bangladesh over three months duration. A fabric inspection machine and a 4-point inspection method were employed in this study. Gout was found as the most frequently occurring defect for each fabric type but not influential for rib fabric. For a significant amount of knitted fabrics, totaling of 55,524.91 m^2 inspected fabric, the most occurring defects were ranked as gout, press-off, hole, miss knit, stain, and tucking and influential defects (based on inspection points) were ranked as gout, press-off, hole, stain, miss knit, and tucking (highest to lowest). In the inspection report, the knitter/inspector mistakenly categorized gout as the most occurring as well as the most influential defect for 1X1 rib fabrics and suggested remedies accordingly.

1 Introduction

In this age of commercialization, the success of any businesses is highly contingent upon the acceptance of their services and products by their target customers. In addition, globalization causes the fashion business, identical to all other businesses, entering into a fierce competition and all parties involved in the global textile and apparel (TA) market are seeking to display their products before customers at the lowest price, but still high in quality. The concept of quality is so pervasive in the TA industry that it has to maintain throughout the entire supply chain. The early detection of any quality deterioration issue will enhance the chance to rectify that defect in a timely and cost-effective manner. For an example, if a hole in the grey knitted fabric, because of faulty machine set up, identified at the beginning of knitting process, it will increase the likelihood of not carrying more holes to the finished fabric's spreading and cutting stage where having more hole could cause rejecting the entire fabric roll. Though quality control and assurance (QCA) is not free, overlooking any lack of quality from any stage of the supply chain causes that product reaching to the customer and eventually rejected by the customer has far more negative consequences and expensive than the initial QCA cost. The existence of defect(s) would reduce the expected performance of the knitted fabric. If a knitwear made out of defective fabric and having defect(s) appeared on a prominent position of that article would readily be seen and rejected by a prospective customer. In the textile industry, the grey fabric quality is often relaxed and hence, overlooked. It is because some of the defects identified in the grey fabric might disappear in the finished fabric stage after the dyeing and finishing process. This is true when both fabric manufacturing and dyeing mills are synced in terms of quality assessment and they are following right approach to fix any quality defect; if not, the cost of the defect incur exponentially until the product is rejected by the ultimate consumer.

While addressing grey fabric quality in a renowned circular weft knitting factory of Bangladesh, the authors experienced some questionable approach practiced by knitters/inspector. Though a number of smart technologies (e.g., image analysis, neural network algorithm or fuzzy logic, artificial intelligence [AI]) are available for the knit fabric inspection, human-centered inspection is still the most reliable and widely practiced method. However, a number of research argued the possibility of implementing AI in the TA industry because it might improve production efficiency and augment the capabilities of their human employees [1]. The very interlooping structure of knitted fabric along with yarn hairiness makes it difficult to use smart technologies for knit fabric than that of woven fabric [2]. The subjective nature of defect detection by knitters often causes wrong emphasizing on frequently occurring defect(s) instead of focusing on influential defect(s) and subsequently, employing wrong quality control approach to minimize the grey fabric defects. Almost all of the previous studies on knitted fabric defects control were based on cumulative defect numbers [3] [4] [5] [6] rather than emphasizing on original quality impacted by the defects (i.e., how these defects influenced fabric roll rejection or acceptance decision). In addition, these studies did not incorporate any standardize fabric inspection method to evaluate fabric quality through defect points. In the actual manufacturing business, knitted fabric quality acceptance is determined by some predetermined point limits agreed upon between the manufacturer and the buyer. Considering the defect size and gravity, if any defect is responsible for the maximum point in the quality inspection report based on the agreed point system, it should be identified as the most influential defect. Different fabric inspection methods (e.g., 4-point system, 10-point system, Graniteville "78" system, Dallas system, and Textile Distributors Institute system) are practiced throughout the world to determine the acceptability of fabrics from a quality standpoint. However, the 4-point system based on ASTM D5430-13 (2017) [7] is widely recognized for knitted fabric inspection [8]. Besides, the 4-point is system is approved by The American Society for Quality Control (ASQC), Textile and Needle Trades Division, The American Apparel Manufacturers Association (AAMA) and is used by the United States Government for all of their piece goods purchased [9]. This study is particularly aimed to evaluate the significance of knitted fabric defects based on their contribution using the widely practiced 4-point system along with their frequency of occurrence on a particular quantity of knitted fabric produced in a renowned knitting mill of Bangladesh.

1.1　Fabric defect types

Fabric defects refer to any abnormality in the fabric that hinders its acceptability by the consumer. From the ASTM D3990-12 (2016) standard, knit fabric defects are sorted as hole, stain, press-off, snag, gout, miss knit, barré, slub, tucking, think place, thin place, bow, dropped stitch, crack mark, float, loose course, skew, snarl, split stitch, spot, and streakiness [10]. According to this ASTM D3990-12 (2016) standard, gout (see Fig. 1a) referred to "foreign matter trapped in a fabric by accident, usually lint or waste"; press-off (see Fig. 1b) referred to "a condition in which the yarn fails to knit and either the fabric falls off the needles or the design is distorted or incomplete"; hole (see Fig. 1c) referred to "an imperfection where one or more yarns are sufficiently damaged to create an aperture"; miss knit (see Fig. 1d) referred to "a deviation from the designated knitting pattern"; stain referred to "an area of discoloration that penetrates the fabric surface"; and tucking referred to "one or more unwanted tuck loops." From the same standard, crack mark referred to "an open place causing a streak of variable length approximately parallel to the length or width"; thick place (see Fig. 1e) referred to "an unintentional change in fabric appearance characterized by a small area of more closely spaced yarns, or by a congregation of thick yarns as compared to the adjacent construction"; loose course referred to "a row of loops in the widthwise direction that is larger, looser, or longer than the stitches in the main body of the fabric"; barré (see Fig. 1f) defined as "an unintentional, repetitive visual pattern of continuous bars and stripes usually parallel to the filling of woven fabric or to the courses of circular knit fabric"; and dropped stitch referred to "an unknitted stitch."

(a) Gout　　　　　　　　(b) Press-off　　　　　　　　(c) Hole

(d) Miss knit　　　　　　　(e) Thick place　　　　　　　(f) Barre

Fig. 1　Knit fabric defect types

1.2　Fabric defect causes and remedies

The sources of grey knit fabric defects could be i) faults in yarn and the yarn package, ii) yarn feeding and yarn feed regulator, iii) machine setting and pattern defects, and iv) machine maintenance [11]. From authors' industry experience and various recognized industry standards (e.g., ASTM D3990-12 (2016), [10], ISO 8499-03 [12] and MIL-STD-1491 [13]), the causes and remedies of various defects on

grey knit fabric are discussed in this section. The presence of dead fibers and other foreign materials (e.g., dyed fibers, husk, synthetic fibers) and clinging of dyed and other types of fibers (flying from the adjacent knitting machines) that embedded in the grey fabric are causes for gout defect. Using yarns free from dead fibers and other foreign materials for knitting and segregate knitting machines with plastic curtains or nets to prevent the fibers flying from the neighboring machines are few remedies for this problem. The grounds for press-off defect are yarn end breakage on feeders and yarn's failure to feed into needle hooks due to faulty feeder position. Adjusting proper yarn tension and feeder position in relation to needle sizes along with using needle detectors would be the solution for this press-off defect. The origins for hole problem are high yarn tension, yarn overfeed or underfeed, high fabric take down force, and obstructions in the yarn passage. The sources for miss knit defect are faulty positive feed system and wrong feeder setting. The reasons for stain related defect are fiber and fluffs accumulation in the needle tricks which remain soaked with oil and excessing oiling in the needle need. Having weaker fabric take-up force, setting dial in higher place, having tighter loop, and setting course density incorrectly act as triggers for tucking defect. Most of these causes are related to the knitting machine operation and therefore, optimum and correct machine set-up is required to reduce grey fabric defects.

In the industry, the grey knit fabric defects should be assessed by type, fault coverage, gravity and the frequency of occurrence instead of focusing only on frequency of occurrence in the fabric. For an instance, the gout is found as a frequently occurring defect in the inspected knit fabric rolls. Based on the quality report, the knitter employs segregating knitting machines with plastic curtains or nets to prevent the fibers flying from the neighboring machines- a quality control approach. Apart from this gout being a frequently occurring defect, if it also exists as an influential defect (based on its gravity and point dominance in the inspection report), the action taken by the knitter is rational and justifiable. However, most of the time, the type of frequently occurring defect(s) and the influential defect(s) are not the same and it makes the quality assurance program somewhat imprudent.

1.3　　Significance of this study

In comparison to the finished fabric quality, there is a paucity of studies on grey knit fabric quality. However, previous studies analogously stressed only on the frequently occurring defects while addressing grey knitted fabric quality [3] [4] [5] [6]. In the study of Sadi et al., they identified five frequently occurring defects (e.g., hole, contamination, dirty spot, oil spot and lycra out), which were accounted for 90.10% of the total defects [6]. In another study, four critical fabric defects (e.g., needle line, hole, yarn variation, and lycra jump) were determined based on their frequency of occurring and these defects were accounted for 80% causes of quality defects [3]. Similarly, other studies focused on classifying defects based on their frequency of occurring [4] [5]. Moreover, these studies used local or, factory terminology when described defects rather than using their standard name (ASTM D3990). To determine the dominant or influential defects from the fabric inspection, this study accentuates using the maximum points occupying defects rather than using their frequency of occurring only. For an example, 1000 gout defects with one point each will yield 1000 points, whereas 300 holes with four points each will yield 1200 points. Based on the previous studies, gout would be identified as dominant defect, whereas in actual situation, hole would be an influential reason for rejecting fabric before gout. In this study, grey weft-knitted fabric quality is investigated using the maximum points occupying or influential defects instead of frequently occurring defects approach.

2　Materials and methods

Quality data of plain single jersey (100% Cotton, 34/1 Ne yarn count, 140 GSM), fleece (100% Cotton, 26/1 Ne yarn count, 300 GSM) and 1X1 rib (100% Cotton, 30/1 Ne yarn count, 200 GSM) were gathered and analyzed from an established knitting factory in Bangladesh over three months duration using 24gg and 18gg for single jersey and double jersey circular knitting machine respectively. A fabric inspection machine (accuracy of checking selvedge: ± 5 mm and accuracy of counting length: $\leq$ 0.50%) and standard fabric inspection method (4-point system) based on ASTM D5430-13 (2017) were employed in this study. The nature of defects, number of defects and points associated with the defects were tabulated and analyzed according to the fabric type to determine their frequencies of occurrence and

influence on the fabric quality report. The Table 1 shows point values of fabric defects according to the 4-point system.

Table 1. Allotted points for fabric defects based on 4-point system

Length of defect in fabric	Demerit points	Holes and Opening	Demerit points
Up to 3 inch	1	Any hole except a pin hole	4
Over 3 inch up to 6 inch	2		
Over 6 inch up to 9 inch	3		
Over 9 inch	4		

The total penalty point is calculated by using Equation (1) for 100 yard^2 fabric. Typically, the acceptable points per 100 yard^2 inspected fabric is mostly dependent on the agreement between buyer and seller. However, this study employed grade *A, B, and Reject* for up to 20, 20-30, above 30 points per 100 yard^2 respectively.

$$\text{Points per 100 yard}^2 = \frac{\text{Total point} \times 36 \times 100}{\text{Total roll length in yards} \times \text{cuttable width in inch}} \qquad (1)$$

3   Results and discussion

Total areas of inspected fabrics were 18405.10 m^2, 27308.67 m^2, and 9811.14 m^2 for single jersey, fleece, and rib fabric respectively. Fabric defects (see in Table 2) were gathered and analyzed according to fabric type and classified according to their presence and dominance. For single jersey fabric, gout was the most occurring defect (accounted for around 2/5th of total observed defects) followed by miss knit, press-off, and hole. Likewise, for fleece fabric, gout was the most occurring defect (accounted for around 3/5th of total observed defects) followed by press-off and hole. However, the presence of other defects (e.g. tucking, barré, dropped stitch) was quite rare in fleece fabric. For the 1X1 rib fabric, both gout and stain were the most occurring defect (jointly contributed for more than 1/2th of total observed defects) followed by hole and press-off (jointly contributed for around 2/5th of total observed defects).

Table 2. Allotted points for fabric defects based on 4-point system

Fabrics	Defect frequency and points	Gout	Press-off	Hole	Miss knit	Stain	Tucking	Crack mark	Loose course	Barré	Dropped stitch	Thick places
Single Jersey	Frequency of defect	124	49	38	56	29	8	7	6	5		
	Defect points/100 sq. yard	1.35	1.07	0.83	1.22	0.32	0.04	0.15	0.13	0.11		
Fleece	Frequency of defect	492	119	117		68	2	10		3	2	
	Defect points/100 sq. yard	3.60	1.74	1.71		0.50	0.02	0.15		0.04	0.03	
1X1 Rib	Frequency of defect	90	61	62	10	88	7		4		6	1
	Defect points/100 sq. yard	1.84	2.49	2.53	0.41	1.79	0.14		0.16		0.25	0.02

Overall, gout was found as the most frequently occurring defect for all fabric types. However, based on gout's points dominance in the inspection report, it was found as the most influential defect for both fleece and single jersey fabric, but not for the 1X1 rib fabric (see Fig. 2). Hole was found as the most influential, yet second most occurring defect for rib fabric. In the inspection report, the knitter/inspector mistakenly categorized gout as the most occurring as well as the most influential defect for 1X1 rib fabric and suggested remedies accordingly. For the grand total of 55,524.91 m^2 inspected fabric, the most occurring defects were ranked as gout, press-off, hole, miss knit, stain, and tucking (highest to lowest). This finding supports the previous study conducted by Hossain, Moin and Mahabubuzzaman [4] and hole was identified as one of the frequently occurring defects [3,6]. Considering the points occupied by these above-mentioned defects (i.e., influential defects), they were ranked as gout, press-off, hole, stain, miss knit, and tucking (highest to lowest).
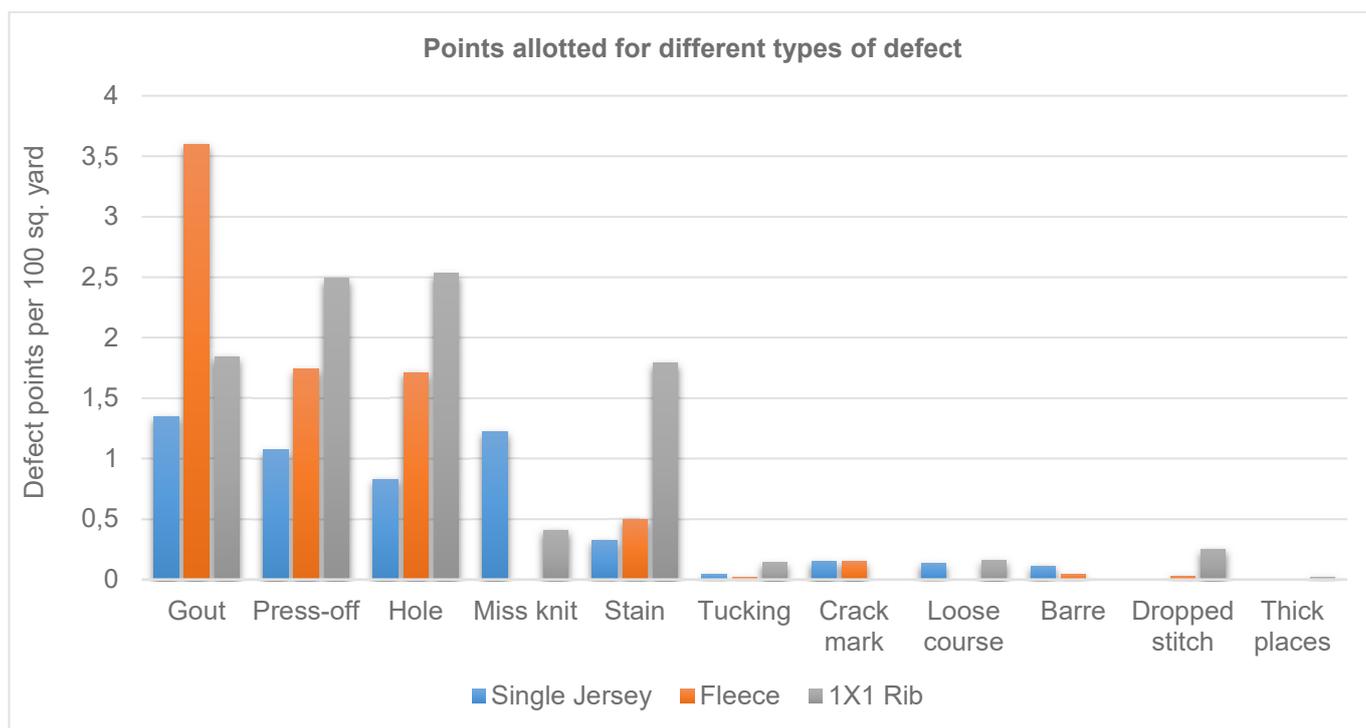

Fig. 2 Defect points allotted for different types of defect

Based upon the principle of frequently occurring defects, similar to previous studies, the gout defect would deserve the knitters' or industry practitioners' the utmost attention to contain it, followed by stain, press-off and hole for 1X1 Rib fabric. In addition, gout, stain, press-off, and hole defects are accounted for 27%, 27%, 19% and 19% of total defects respectively based on their frequency of occurring for the same fabric (Fig. 3, inner pie chart). However, this study made a case to see these defects in terms of their ultimate contribution to the fabric roll rejection or acceptance decision based on their points allocation in the fabric inspection report. In the outer pie chart of Fig. 3, gout, stain, press-off, and hole defects are accounted for 19%, 19%, 26%, and 26% of total defect points respectively in the inspection report. The fabric inspector practices defect points as a guideline to accept or reject the fabric roll instead of cumulative defect numbers. Therefore, unlike previous studies, this study identified the importance of shifting knitters' or industry practitioners' attention from cumulative defect numbers to maximum point allocating defects for knit fabric and address corrective actions accordingly. In summary, categorizing influential defects, grounded on the highest point allocation, would ensure the right approach for quality assurance for the grey knit fabric.
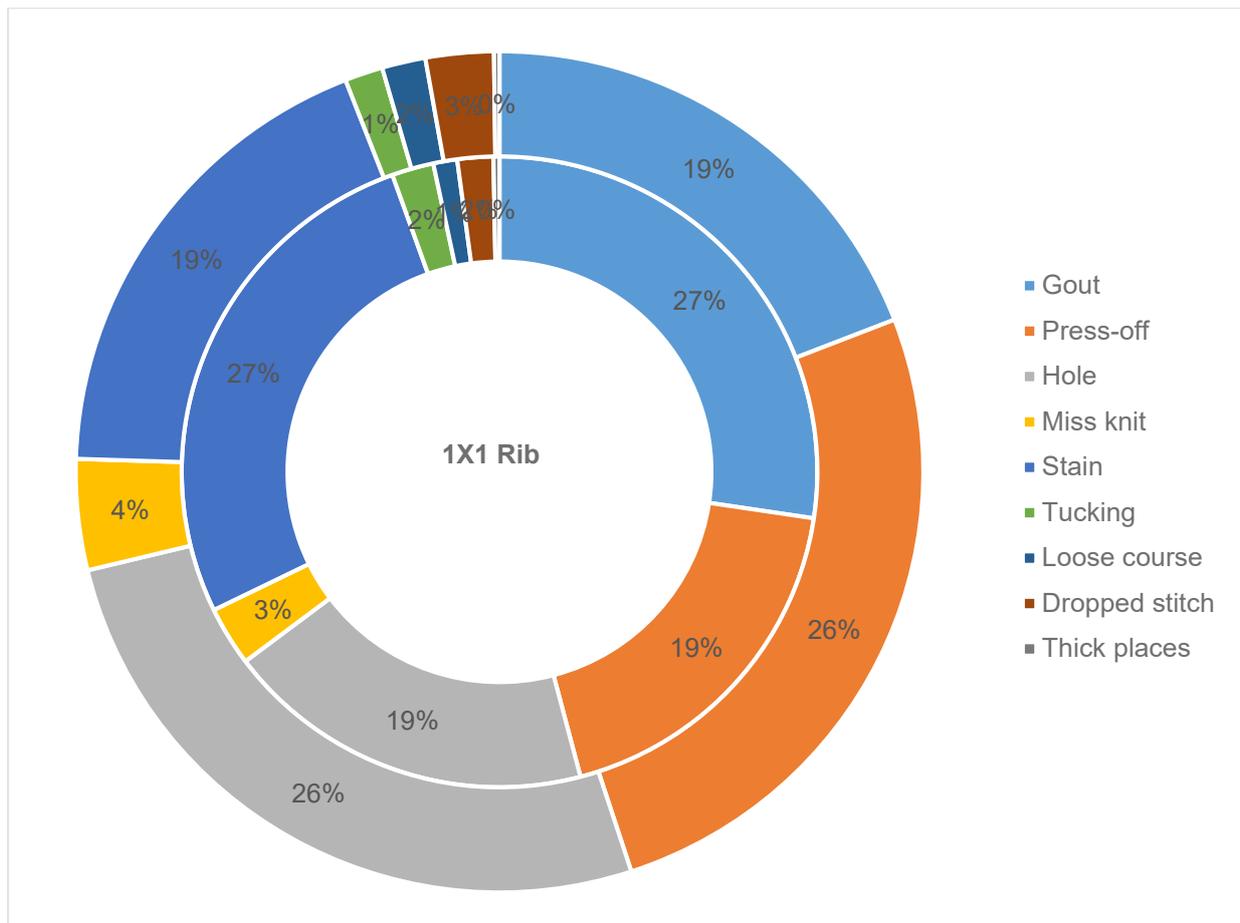
Fig. 3 Frequency of defects (inner circle) vs. defect points/100 yard^2 (outer circle) for 1X1 Rib fabric

4 Conclusions

Defects detection in the grey fabric state is very crucial as it gives the scope of rectifying the faults at the early stage of manufacturing process. However, some defects like spot, needle line (vertical crack mark) are noticeable in the grey fabric state could be invisible after dyeing. Alternatively, some defects (e.g., barrè) are imperceptible in the grey fabric state could be discernable after fabric coloration. The best approach would be maintaining a database of defects over a couple of years and coordinate the outcome with the dyeing department to determine which influential defects should address in the grey state through a quality assurance program. In this study, it was not possible to justify the presence and impact of observed different defects on finished fabric quality. This study was conducted in a particular factory in Bangladesh and therefore, the researchers were unable to justify the outcome of this research. The sources of knitted fabric defects are mostly— yarn fault, knitting fault, and fault occur due to the environment [11]. Therefore, grey weft knit fabric quality should be addressed and coordinated throughout the entire supply chain. Many recognized literatures and standards such ASTM D3990-12 (2016) [10], ISO 8499-03 [12] and MIL-STD-1491 [13] captured knit fabric defects/faults/flaws quite elaborately. However, a more in-depth future study is warranted to identify underlying potential root causes and eliminate grey fabric defects permanently. In this study, it is evident that knitter/inspector wrongly categorized gout as influential and the most occurring defect for all fabrics. The findings, therefore, indicate the action plans should be taken on priority basis for an effective quality assurance program in the knitting floor.

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