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Using the Lean Six Sigma to Reduce Fit Variation in Denim Jeans Manufacturing

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Abstract:
Fit inconsistency is a major concern for consumers that drives repeat purchases; and with increasing online sales it has become more important than ever. This paper describes how Lean Six Sigma tools help in identifying causes of fit variation in denim jeans manufacturing, and how it can be reduced. It shows how fit variations are verified through measurements and how a detailed process flow chart is created to describe processing steps. This helps in identifying potential sources of fit inconsistencies. Experiments are set up to determine which process steps have the most impact on inconsistencies. The results of the analysis are used to recommend and implement improvements for processing. A significant reduction in fit variation could be achieved.

Keywords: Lean Six Sigma, Denim Jeans, Fit Variation, Process Improvement

1.0 Research Gap addressed:

The use of Lean Six Sigma's DMAIC (Define, Measure, Analyse, Improve, Control) process has not previously been described in the denim apparel manufacturing environment. DMAIC is a data-driven improvement system that looks for incremental improvement. The simple yet powerful five-step program provides a roadmap to process improvement, using quality management and statistical tools (ASQ, n.d.; Khairnar, 2019).

2.0 Key Findings:

- Use of DMAIC process is highly applicable to addressing fit variation in denim jeans manufacturing.
- A high degree of manufacturing complexity (large number of process steps) requires the use of statistical tools.
- Understanding the technical process steps is critical in creating a cause-effect diagram

3.0 Method /Experiments

The five-step DMAIC process was applied to a denim manufacturing setting in the following manner:
Define: the problem was defined in terms of business implications (i.e., loss of sales and customer loyalty) and in technical terms (i.e., waist and inseam fit variation). Fit variation was defined as large deviations from the specified limits for waist and inseam measurements. A company team consisting of the VP of Operations Excellence, the Senior Director of Quality Assurance, and the Quality Assurance Manager, believed that these deviations were the cause of potential and actual loss in sales and customer loyalty.
Measure: Existing company audit data on fit variation (defined as variation of actual size from the planned size in waist and inseam) over a period of seven months was analysed to determine the degree of fit variation occurred in the current manufacturing process. The primary issue of concern was the range of the variation, which in some cases exceeded one full size in either direction. Fit variations were measured at various points in the process by measuring actual vs. planned waist and inseam dimensions, and increased variations were noticed after the finishing or laundry processes.

At the beginning of the study, waist and inseam measurement audit data from the company was analysed to determine deviations from the tolerance limits. The measurements were summarised using descriptive statistics for 27 steps in the manufacturing process. This was done by measuring planned vs. actual dimension for these process steps (waist and inseam after garment construction, fabric dimensions prior to garment construction). After consulting a team of experts close to the manufacturing process, laundry and pressing were identified as areas with the largest shrinkage of fabric (resulting in fit variation). Experiments were designed to reduce the shrinkage. However, before the experiments began, a gauge repeatability and reproducibility (Gauge R&R) study (conditioned at 65% RH and 20^{0}C for at least 24 hours after washing and drying; linear shrinkage in warp and weft directions were measured by using a shrinkage % ruler) was conducted on on12 fabric swatches (18X18 inches each): 2 rigid cotton, 2 washed cotton, 2 rigid bi-blend, 2 washed bi-blend, 2 rigid tri-blend, and 2 washed tri-blend. Further, 3 operators who currently measure the shrinkage in the facility were included. Each fabric swatch was measured three times, both in warp and in filling direction. The swatches were measured in random order.

The data were analysed using a random effects N-way ANOVA. Once the measurement system was acceptable, experiments were conducted to reduce the shrinkage. Screening designs were used, and the results analysed using N-way ANOVA and Tukey's HSD. Waist and inseam variation data from several plant locations across the globe were compared, which showed similar results. This meant that regional differences in training or experience could be excluded as a cause of fit variations. A high-level process map with 52 manufacturing steps was created (Fig. 1).
Analyse: The purpose of this step is to find the root causes of the variations (ASQ, n.d). With the help of the process map, members of the company team and the research team conducted brainstorming exercises and created cause and effect diagrams (Fig. 2) to determine possible areas where the variation in waist and inseam might occur.
Improve: Based on the analysis, changes to the manufacturing process were recommended and implemented.
Control: After implementing changes to the manufacturing process, trend charts were used to monitor monthly changes in the range of fit.

4.0 Results & Discussion

The results of the Gauge R&R study showed that only an extremely small amount of variability should be due to the measurement system (0.27% for the warp direction, and 0.01% for the filling direction). This indicates the accuracy (over 99%) of the measurement system employed in this study.
The initial brainstorming meetings of the selected company team (VP of Operations Excellence, the Senior Director of Quality Assurance, and the Quality Assurance Manager) and the primary researchers and plant visits identified and developed the process flow chart (figure 1) and the cause-and-effect diagram in figure 2. These exercises led to several potential areas where variation was likely to occur. Laundry, drying, and pressing were considered very promising areas because heat and moisture typically impact shrinkage, and these areas were studied in more detail; other areas were set aside for future study.
Additional experiments were conducted to determine the influence of different purchase orders (POs) within the same fabric code of incoming materials for the two blended fabrics, and for three different drying temperatures (60°C, 71°C, and 82°C) that represent standard settings in Fahrenheit (140°F, 160°F, and 180°F). The statistical results showed that the variation was more significant for blended (bi-blend and tri-blend) fabrics than 100% cotton fabrics; thus, the study focused more on blended fabrics. During the above-mentioned brainstorming sessions, dryer temperatures had been expected to play a major role in shrinkage variation; however, since lower temperatures required longer drying times, shrinkage turned out to be higher at lower temperatures. Shrinkage variation, however, could statistically not be attributed to the dryer temperature. Different POs within the same fabric code showed a high statistical significance (r^2 of 0.988902).

Fig. 1: Process Flow Chart of Denim Manufacturing

(S7 is a spreading machine, J-Stitch is a sewing machine creating the J-shaped seam around the zipper, and J63 is a laser guided quality control machine)

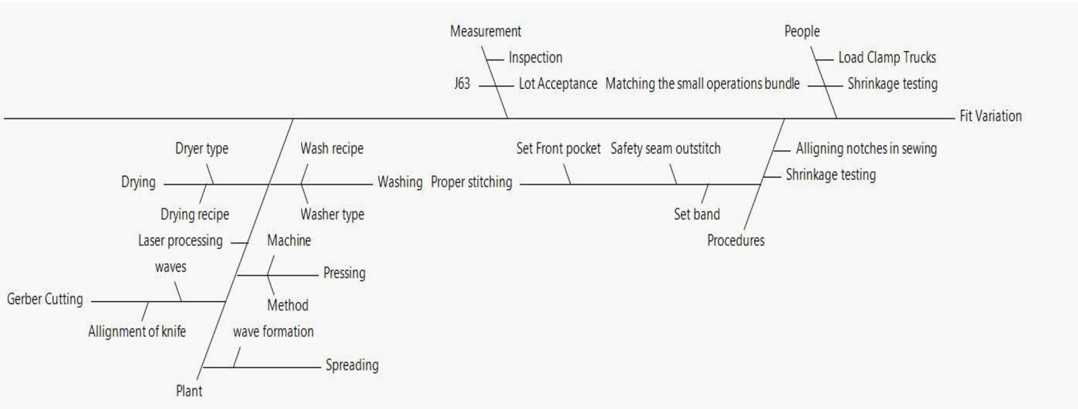

Fig. 2: Cause and Effect Diagram

As a result of this research, the company started to perform shrinkage tests on 100% of the incoming blended fabrics as opposed to previously less than 40%. This new incoming fabric testing protocol allowed the company to correctly predict the shrinkage behaviour of every single fabric bale and to adjust for the specific shrinkage in cutting and sewing. This recommendation is considered the improvement step in the DMAIC process. During the control step in the DMAIC process, the waist and inseam fit consistencies were tracked over time after introducing the new testing protocol. In the following months, this showed a decrease in the fit variation for men’s waist of 23.1%, and a decrease in the fit variation for women's waist was 12.5% (see Fig. 3). This decreased range in fit variation was considered sufficient by the company team to improve market perception.

It should be expected that further improvement may be achieved when using the methodology on other identified process steps that were not analysed in this study. This makes the DMAIC process a valuable part of ongoing quality improvement efforts.

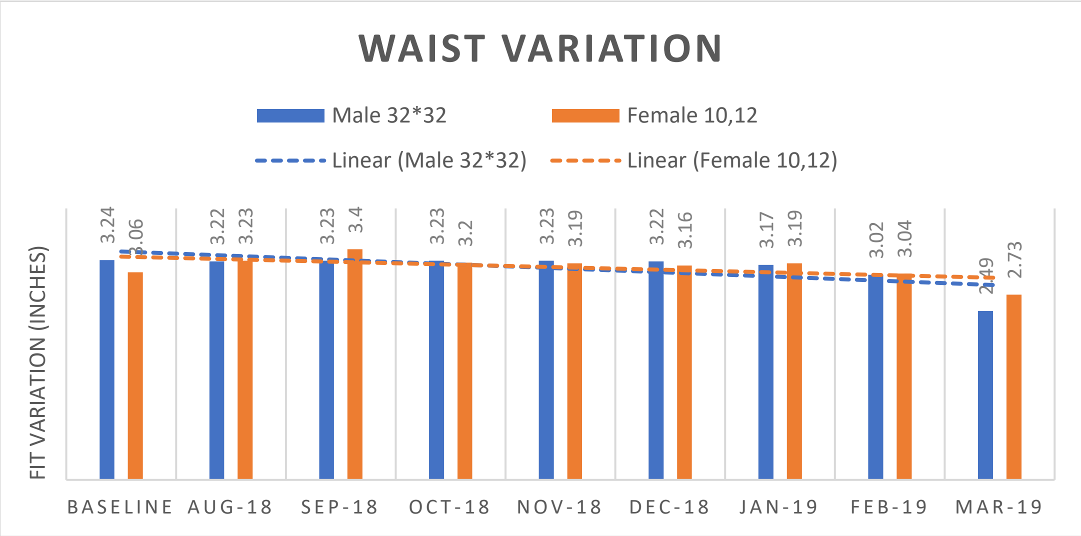

Fig. 3: Change of fit variation over time

5.0 Theoretical Background

The causes for sizing and fit variations are frequently attributed to sizing standards (Dooley, 2013), or cutting and sewing inconsistencies. However, within a single brand they are becoming inacceptable, especially as online shopping reduces the opportunity to try on clothing pre-purchase. The DMAIC process proved very valuable in systematically defining, measuring, analysing, and improving the described problem in this textile manufacturing setting and shows how the improvement could be controlled and verified. The wide range of products and process steps made the statistical tools invaluable. Understanding the technical process steps was critical in creating a cause-effect diagram and in analysing any of the statistical results. Use of the DMAIC process allowed eliminating some of the suspected quality problems occurred early in the process, thus improving the efficiency of problem solving. Examples of this were fabrics that were affected and those that were not, and the different drying temperatures that did not impact shrinkage variation.

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