Challenges and Opportunities of Product Fitting for Denim Manufacturers: A Reflexive Thematic Analysis Through the Lens of Engineering Design Process Model

Jakir Hossain and Hyo Jung (Julie) Chang
Texas Tech University

Introduction: North America represents the biggest denim market in the world (Muthu, 2017). In 2016, more than 30 percent of the revenue to the global market was contributed by this US market (Salfino, 2018). This is not only because of historical reasons (e.g., cowboys/miners wearing blue jeans in the early 1920s), but also because of the casual lifestyles enjoyed by Americans in this day and age. According to the survey conducted by Cotton Incorporated Lifestyle Monitor (2018), approximately 59% of consumers love to wear denim, and around 61% wear denim at least three times a week. As this market is growing in the US, there is a need for accessible manufacturers to provide the denim products needed by these consumers. Especially, Bangladesh is one of the top denim suppliers to the US. However, they have a tough time nowadays for multiple reasons, such as increasing raw material costs, environmental pollution, fit problems, washing variations, and finishing problems (Halim et al.,2021). Among them, fit is one of the critical issues as it is directly related to time, money loss, and consumer satisfaction (Csanak, 2015). The fit is also one of the crucial factors in determining the quality of denim production. Therefore, this paper aims to take the initiative to identify the fit-related challenges that denim manufacturers face during production. In addition, we explore the opportunities to solve these pains.

Literature Review: ***Denim Fabric.*** Denim is a warp-faced cotton fabric where white weft yarn passes under one or two colored warp yarn following a twill weave design (Hossain et al., 2020). At first, denim garments are produced using 100% cotton-based woven fabric. Therefore, they can stretch only in one direction and have fewer fit-issues. On the other hand, stretch denim, including polyester, has increased market share because of the extensive demand (Choudhary et al., 2018). The increasing amount of elastane in denim fabrics increases comfort, but it intensifies the fit problems during pattern making, sewing, washing, and pressing (Eryuruk, 2019).

Denim Garments Production Process and Fit Problems. The denim garment production starts with making patterns, grading, and then marker making according to the buyer-approved design. Pattern makers create all the patterns considering product styles, sizes, and shrinkage of the fabric (Liu et al., 2010). The fabric-cutting process is followed by spreading fabric on the cutting table, marker placing, cutting, sorting, numbering, bundling the cut panel, and finally inputting to sewing. After completing the sewing process, garments are sent to the washing section according to the buyer's requirements. Washing is the base of denim finishing, usually applied for already sewn garments (Ata et al., 2020). Therefore, during the whole washing process, garments are affected by the entire complex of several factors such as various washing solutions, creasing, temperature, etc. (Juciene et al., 2006). Industries are working to minimize measurement defects, but sometimes their efforts need to be better to reach the expected measures.

The Engineering Design Process (EDP) Model. The engineering design process theory emphasizes open-ended problem-solving and encourages the creation of innovative solutions (Eder, 2014). This model posits the importance of the design thinking process to identify the critical problems during the manufacturing process and make those problems simple to solve (You & Hands, 2019). Implementing an engineering design process theory can be an effective way to produce the product successfully, and this includes seven stages: problem recognition, problem definition, exploration of the problem, search for alternatives: evaluation and decision making, specification of the solution, and communication of solution (Regan & Kincade, 1998). In this study, we used these seven stages (summarized into five) to gain insight into the apparel production process, its problems related to fit, and alternative and potential solutions.

Method: This study employed a qualitative research method of one-on-one in-depth interviews. The participants of this study were experts in their respective divisions in the different denim manufacturers in Bangladesh. The open-ended interview questions were developed to understand their fit-related challenges, followed by the demographic questions (Table 1). A total of ten interviews lasted from 30 to 60 minutes, where data saturation was reached. All recorded data were transcribed in English, and we interpreted our data through the lens of the engineering design process model using a reflexive thematic approach (RTA). This approach was developed by Clarke and Braun (2006). It explores qualitative data to answer broad or limited research questions about experts' experiences, their views and perceptions, and representations of a given incident (Braun et al., 2006). It is an iterative process to interpret the collected data and to provide theoretical assumptions of the interpretations. In this study, we used a deductive way of RTA (i.e., theme development based on the existing models) (Byrne, 2021).

Table 1. Demographic Information of Participants

Pseudonym	Gender	Age	Company	Position	Role
Alex	Male	32	Pacific Jeans	Manager (Washing)	Research & Development
David	Male	28	Nassa Group	Asst. Merchandiser	Merchandising
James	Male	50	Nassa Group	Pattern Master	Pattern Making
William	Male	45	Nassa Group	Sr. Quality Inspector	Garments Quality Inspection
Michael	Male	33	Pacific Jeans	Asst. Merchandiser	Merchandising
Jackson	Male	31	Ananta Group	Quality Assurance Officer	Sample Quality Inspection
Jack	Male	45	Nassa Group	Pattern Master	Pattern Making
Joseph	Male	40	ZXY	Buying Technician	Garments Quality Inspection
Asher	Male	35	Denim Flocks	Managing Director	Communication with Buyer
Sarah	Female	32	Ananta Group	Merchandiser	Merchandising

Results: The findings of this study were organized into five categories: *Fit Problems Occurred, Exploration of Fit Problems, Search for Alternatives, Evaluation and Decisions,* and *Suggested Solutions*. First, for *Fit Problems Occurred*, each participant narrated unique and common problems in each division, e.g., "Lycra breakage is one of the common problems in our sewing and washing divisions." Second, for the *Exploration of Fit Problems*, the participants identified specific reasons for these problems, e.g., "Denim fabric for skinny jeans has a bigger shrinkage problem. This is one of the main problems causing the fit issue." Third,

Table 2. Research Findings Based on the Engineering Design Process Model

Denim Garment Production Stages	Manufacturing Division	Fit Problems Occurred in Each Division	Exploration of Problem	Alternatives	Evaluation and Decisions	Suggested Solutions with Technology
1. Design 2. Pattern Making 3. Fit Sample Making 4. PP Sample Making 5. Production Patterns 6. Marker	Sample Pattern	❑ Front has drag lines from shoulder to center ❑ Shoulder is too slope ❑ Dragging at back crotch ❑ Back rise too tight ❑ Side seam dapping ❑ Side seam bubbling	❑ Improper balancing ❑ Wrong proportion ❑ Incorrect alteration ❑ Insufficient technology ❑ Insufficient skill	➢ Make trial sample ➢ Check it on manuequin ➢ Rectify the pattern accordingly	❑ Increase front neck width ❑ Move the front and/or the back shoulder up at the armhole ❑ Remove access fabric ❑ Move side seam and center back to outside ❑ Move up side seam at leg ❑ Decrease hip width at side seam	➢ Use 3D software such as CLO to make pattern and check the fitting virtually
7. Fabric Spreading 8. Fabric Cutting 9. Sorting and Bundling	Cutting	❑ Incorrect tension of plies ❑ Distorted garment's part ❑ Grain line misplacement	❑ Fabric spread too tight/loose ❑ Fail to follow the marker line ❑ Fabric cutting in wrong way	➢ Do trial cut before bulk cutting ➢ Do manual inspection before cutting	❑ Fabric should spread face down, face-up, or face to face as required ❑ Use the right cutting machine and maintain proper machine parameters during cutting ❑ Pattern must lay down with the grainline parallel to the selvedge	➢ Automatic spreading machine ➢ Automatic cutting machine ➢ Robot operator in cutting division ➢ Scanner to detect the defects
10. Sewing 11. Washing	Sewing & Washing	❑ Ropy hem ❑ Drag line ❑ Lycra breakage ❑ Twisted legs ❑ Loss of elasticity ❑ Dimensional change	❑ Hem is not laying flat and is skewed ❑ There is not enough fabric in the sewing area ❑ Coarser needle size and improper stitch tension ❑ A rotation between different panels of a garment ❑ Decomposition of spandex fiber ❑ Improper shrinkage system	➢ Do inspection in finishing section ➢ Rectify it manually ➢ Do some sewing process after washing	❑ Make sure the operator gets the hem started correctly in the folder before starting sewing. ❑ Fold a tuck of fabric all around the garment ❑ Use finer and a ballpoint needle for each machine ❑ Match the front and back properly before starting sewing ❑ Strictly maintain the washing temperature, time, and chemicals properly ❑ Check the shrinkage percentage	➢ Automatic sewing machine ➢ Robot operator in sewing and washing division ➢ Scanner to detect the measurement discrepancy
12. Ironing/Finishing 13. Final Inspection 14. Shipment	Finishing	❑ N/A	❑ N/A	➢ N/A	❑ N/A	➢ Scanner to detect the measurement discrepancy

Search for Alternatives; possible alternative solutions for each problem were described, e.g., "Lycra breakage during washing at the bar tack area is a common problem, and we do bar tack stitch after washing instead of before." Fourth*, regarding Evaluation and Decisions*, they analyzed the possible problems and how to evaluate them, e.g., "Before cutting, we check the shrinkage and adjust the pattern to avoid measurement problems during washing." Fifth, for *Suggested Solutions*, the participants talked about technologies that can solve the issues, e.g., "The technological innovation such as an auto-cutting and a spreading machine may help to solve those problems." The findings of this study are summarized in Table 2.

Discussion and Implications: By applying the engineering design process model, we could understand the specific fit-related problems denim manufacturers in Bangladesh face (Eder, 2014). They have tried to solve these issues manually, but fit-related problems still exist. Participants agreed that one fundamental way is to extend the affordability and feasibility of the technology (e.g., 3D sampling). The limitation of this research is that the participants from different divisions discussed diverse technical issues, and some of them were tough to understand without physical presence. Future research can examine the effects of real technological solutions and how these solve those fit problems of the manufacturers.

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