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THE EFFECT OF KNITTED STRUCTURE ON THE QUALITY OF KNIT FABRIC FOR SHOE MATERIALS USING STOLL WEFT KNITTING MACHINES

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Abstract: One of the existing on the market today is knitted sportswear that is used for sports and daily activities because of the convenience and comfort it provides. One of its advantages is its durability. The durability of the fabric is closely related to the upper flat knitted stitch, to meet people's needs for trainer functional and decorative performance, it is very important to research the stitch. Flat Knitted Upper shoe shape is obtained by reorganizing the looping, tucking, floating, transfer, racking, and other process modules according to the knitted design, to form the fabric structure with certain rules and the fabric durability reaches perfection. Forming the upper shoe material. Two designs (that is, functional design and decorative design) are proposed for the formed upper organizational structure, to better take advantage of its shaping advantages, meet the durability requirements of upper materials, and achieve good decorativeness. This study aims to make a product that at least has the same quality as the comparison of an existing product, Diadora 91115 NV Alonzo, in terms of quality, comfort such as air permeability, fabric density, thickness, and durability of footwear such as break resistance, water resistance from fabric. The product was produced in Stoll CMS 530 HP by using two raw materials (yarns), polyester 33 Tex and Cotton Carded Ne_1 32/2. Polyester and Cotton were chosen as raw materials for making these shoes to obtain 2 different properties from each material for these shoes. Polyester has low moisture absorption properties, good resilience and dimensional stability, and excellent wear resistance. In addition to modifying the properties of each characteristic, plating techniques were used to obtain motifs to increase the aesthetic value of the fabric. Three different knitted fabric structures were designed on M1 Plus 6.7.056. As the primary structure, knit structure design 1 used tubular and purl knit structures to produce a

replica of the knit structure of the Diadora shoe fabric. Knit structure design 2 and knit structure design 3 used knit structure 1 as the primary structure design, which has the knit structure replaced by a 1x1 Rib structure in the fifth course for Knit structure design 2 and in the second and fourth Courses for Knit structure design 3. The evaluation and testing of these three knitted fabrics and existing products (Diadora 91115 NV Alonzo) were conducted for fabric construction (CPI, WPI), fabric density, and thickness. Additionally, air permeability, water resistance, and burst strength were conducted to determine its potential as shoe materials. As a result, in terms of fabric construction and thickness, knit structure design 3 has a close number of CPI and WPI as the existing product (Diadora). Nevertheless, all three knit structures have less fabric density which has likely more lightweight than Diadora. In terms of air permeability and burst strength properties, knit structure design 2 has better performance of all structure comparisons by 69.7 $cm^3/cm^2/s$ and 1150 kPa, respectively.

Keywords: knitted shoes, knitted structure, quality, weft knitting

1. INTRODUCTION

Originally the shoe manufacturing process used leather, rubber, denim, and canvas to recently develop knitting technology, such as water resistance, fabric-breaking strength, flexibility, and air penetration. Therefore, from this trait found in knitted shoes other than that, the manufacture of the top part of knitwear footwear made of one piece of cloth eliminated the need for a traditional cut and sewing production process. The ability to adapt to shape and durability improvements in knitted structures makes it ideal for creating complex parts or adapting to complex shapes.

Knitted structures are continuously built-up from push after push of intermeshed circles. The properties of a knitted structure are generally decided by the interdependency of each stitch to its neighbors on either side and over and underneath it. Based on the journal Making Upper Shoe based on ergonomics (Zhiwen Lu. et al. 2016) The upper part in the form of a flat knit is obtained by reorganizing the looping, tucking, floating, transfer, and other process modules according to the knitting requirements. This research hypothesizes that there are differences in the structure of the bond that affect the quality of the fabric obtained, namely thickness and fabric density, air penetration, fabric burst strength, and water resistance.

Diadora is one of the well-known companies that design and progress the outer materials of sports footwear in terms of quality and usefulness. Diadora 91115 NV Alonzo has upper shoe material produced by knitting. Such upper has the requirement to have characterized by high durability, accompanied by optimum lightness, breathability, and flexibility. it was developed using flat knitting machines produced by Stoll.

This research was conducted to determine the effect of the knitted structure, starting by taking a sample of one shoe from the market and testing the fabric construction. After obtaining the specifications of the shoe, the material used is analyzed. In this product with Polyester Cotton material, it has a function as humidity management and body temperature regulation. Secondly, modifications to the structure of the bond were carried out, and the manufacture of fabric products on the "Stoll CMS 530 HP" knitting machine. After that, several evaluation tests were carried out to ensure the quality of the product produced and to meet the quality of the shoes concerning the Diadora 91115 NV Alonzo to get the comfort and durability of the product.

2. Materials and Methods

2.1 Materials

In this present study, shoes from Diadora 91115 NV Alonzo were used to compare existing products. The shoe material is constructed with two different yarns, Polyester 33 Tex and Cotton Ne_1 32/2. Knitted fabric was produced using Stoll CMS 530 HP flat knitting machine while assisted by M1 Plus 6.7.056 Design software to design knit structure fabric making.

2.2 Methods

Diadora 91115 NV Alonzo construction evaluation

Specifications and construction of the fabric on Diadora 91115 NV Alonzo testing were performed by Indonesian National Standard SNI 08-0458-1989, determination of yarn type and size as well as the knit structure design.

Knit fabric Production

Knit structures based on the construction evaluation of Diadora 91115 NV Alonzo were used as primary knit structure designs to produce knitted fabric. That knit structure consists of tubular and purl knit structure named knit structure design 1. The variation of knit structure design replaced tubular dan purl knit structure with Rib 1x1 and interlock in five courses each repeating design. For knit structure design 2, on the fifth course, a Rib 1x1 knit structure was used while the first to fourth courses used a tubular knit structure. While knit structure design 3 used an interlock knit structure on the second and fourth courses, and the rest of the repeat design used a tubular knit structure.

Analysis of fabric construction of knitted Fabric

These three different knitted fabrics were characterized in terms of course per inch (CPI), wale per inch (CPI), fabric density, and thickness. CPI, WPI, and fabric density were determined under Indonesian National Standard SNI 08-0458-1989, while the thickness of each sample was tested by Indonesian National Standard SNI ISO 5084: 2010.

Bursting strength analysis

Indonesian National Standard SNI ISO 13938 - 1: 2010 Textiles tear strength of the fabric Part 1: Method of testing the strength and swelling of the hydraulic method was used to determine the bursting strength properties.

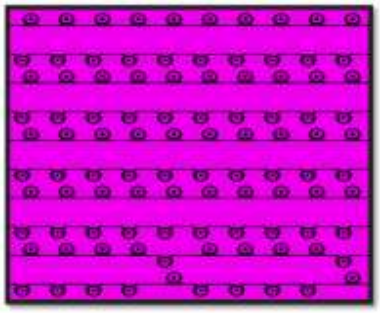
Air permeability and water resistance analysis

The air permeability test was performed by the standard ISO 7231. While Indonesian National Standard SNI 08-0278-1989 was carried out to perform water resistance properties of each sample knit fabric.

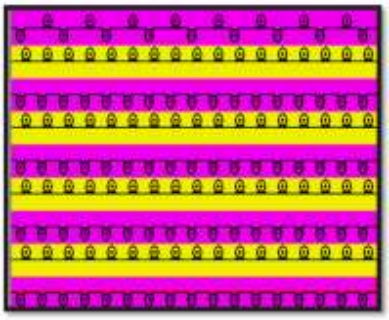
3. RESULTS

3.1. M1 Plus Program Design 6.7.056 – Knit Structure Design

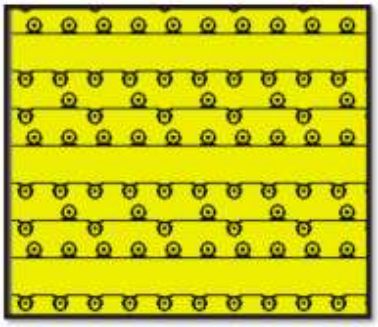
Diadora 91115 NV Alonzo was used as the primary knit structure design to produce knitted fabric. That knit structure consists of tubular and purl knit structure named knit structure design 1 as shown in Figure 1a. For knit structure design 2, on the fifth course, a Rib 1x1 knit structure was used while the first to fourth courses used a tubular knit structure (Figure 1b). While knit structure design 3 used a Rib 1x1 knit structure on the second and fourth courses, and the rest of the repeat design used a tubular knit structure (Figure 1c).



(a)



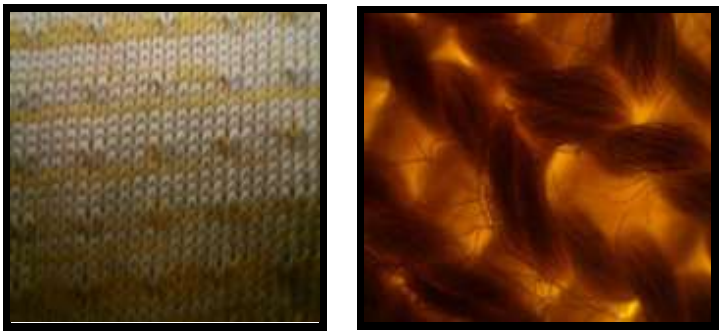
(b)



(c)

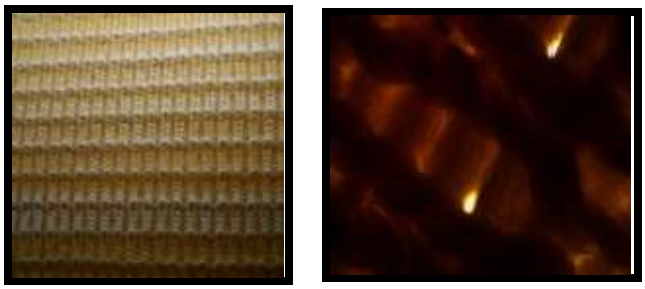
Figure 1. Knitted structure design using M1 Plus Program Design 6.7.056 (**a**) knit structure design 1 (**b**) knit structure design 2 (**c**) knit structure design 3.

The top view image and its image magnification of the three knit structure fabrics were presented in Figure 2, Figure 3, and Figure 4 for knit structure design 1, design 2, and design 3, respectively.



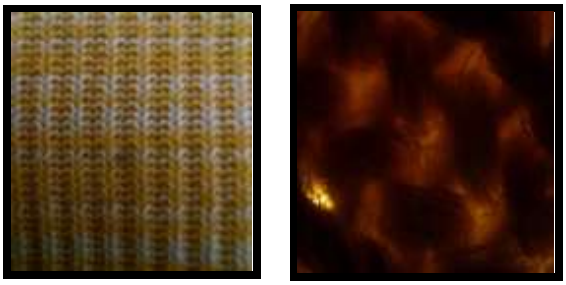
(a) (b)

Figure 2. Knitted structure design 1 (**a**) knit fabric image (**b**) fabric image magnification



(a) (b)

Figure 3. Knitted structure design 2 (**a**) knit fabric image (**b**) fabric image magnification



(a) (b)

Figure 4. Knitted structure design 3 (**a**) knit fabric image (**b**) fabric image magnification

3.2. Spesification and Fabric Contruction Analisys

Table 1 showed the evaluation result in terms of fabric construction of Diadora 91115 NV Alonzo as a comparison product to three different knit structure fabrics. Diadora 91115 NV Alonzo has the largest yarn diameter compared to three knit structure fabrics. Nevertheless, Diadora 91115 NV Alonzo has the least number of loop formations in either course direction or wale direction.

Table 1. Specification and Fabric Construction

Specification	Diadora	Structure 1	Structure 2	Structure 3
CPI	25	36	38	24
WPI	16	18	18	18
Thread Number	Td 649.2	33 Tex Ne 32/2	33 Tex Ne 32/2	33 Tex Ne 32/2
Raw material	60% Polyurethane 40% Polyester	50% Polyester 50% Cotton	50% Polyester 50% Cotton	50% Polyester 50% Cotton

Fabric density and thickness test results of Diadora 91115 NV Alonzo and three knit fabrics were presented on Tabel 2. Diadora 91115 NV Alonzo has the most fabric density compared to three knit structure fabrics. Although knit structure 2 and knit structure 3 have a close thickness with Diadora 91115 NV Alonzo, all three knit structures have less fabric density which has likely more lightweight than Diadora.

Table 2. Fabric Density and Thickness

Specification	Diadora	Structure 1	Structure 2	Structure 3
Fabric Density (g/m^2)	755	620	676	671
Thickness (mm)	2.18	1.77	2.21	2.49

3.3. Bursting Strength Analysis

The burst strength test result was presented on Tabel 3 which has the strength of Fabric to resist bursting and the time-consuming until burst.

Table 3. Bursting Strength of Knitted Fabric

	Diadora	Structure 1	Structure 2	Structure 3
Bursting Resistance (kPa)	950	1130	1150	980
Burst Time, seconds	30	29	32	34

3.4. Air Permeability Analysis

The measure of airflow through a given area of knitted fabrics was shown in Table 4. Diadora 91115 NV Alonzo has the lowest airflow (air permeability) compared to the three knitted fabrics. While knit structure design 2 dan knit structure design 3 have better air permeability by about 40% than Diadora has.

Table 4. Air Permeability of Knitted Fabric

	Diadora ($cm^3/cm^2/s$)	Structure 1 ($cm^3/cm^2/s$)	Structure 2 ($cm^3/cm^2/s$)	Structure 3 ($cm^3/cm^2/s$)
n	10	10	10	10
Avg.	40.1	69.5	69.7	41.7
Min.	37.0	65.2	67.8	39.7
Max.	43.7	74.7	72.4	44.0
CV	4.80%	4.29%	1.84%	3.20%

3.5. Water Resistance Analisys

The measure of the amount of water leakage and water absorption of knitted fabrics were shown in Table 5. Diadora 91115 NV Alonzo has the lowest water absorption compared to the three knitted fabrics. While knit structure design 3 has the most water absorption and the least amount of water leakage compare to Diadora and the rest of the knitted fabrics.

Table 5. Water Resistance of Knitted Fabric

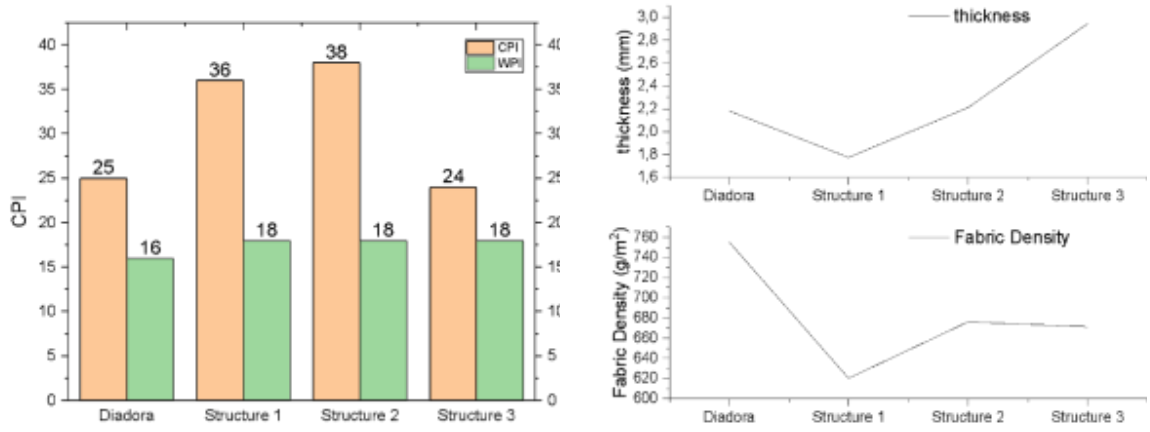
	Diadora	Structure 1	Structure 2	Structure 3
Initial Weight (gram)	14.23	10.76	10.74	12.82
Final Weight (gram)	17.59	15.58	15.39	18.85
Water Absorption (%)	23.61	44,79	43.2	46.64
The amount of water leakage (mL)	11	12	14	10

4. DISCUSSION

4.1 Specification and Fabric Construction Analysis

The number of loop formations in either course direction or wale direction could affect the density of the knit fabric and its thickness. It also depends on the type of knit structure and yarn diameter.

Structure 1 and structure 2 have a similar number of loop formations in course direction because of the number of tubular knit stitches being used. In five courses of each repeating design, the tubular knit stitch was used from the first course to the fourth course. Otherwise, structure 3 used Rib 1x1 knit stitch on the second course and fourth courses. Therefore, structure 1 dan structure 2 have the largest CPI.



(a) (b)

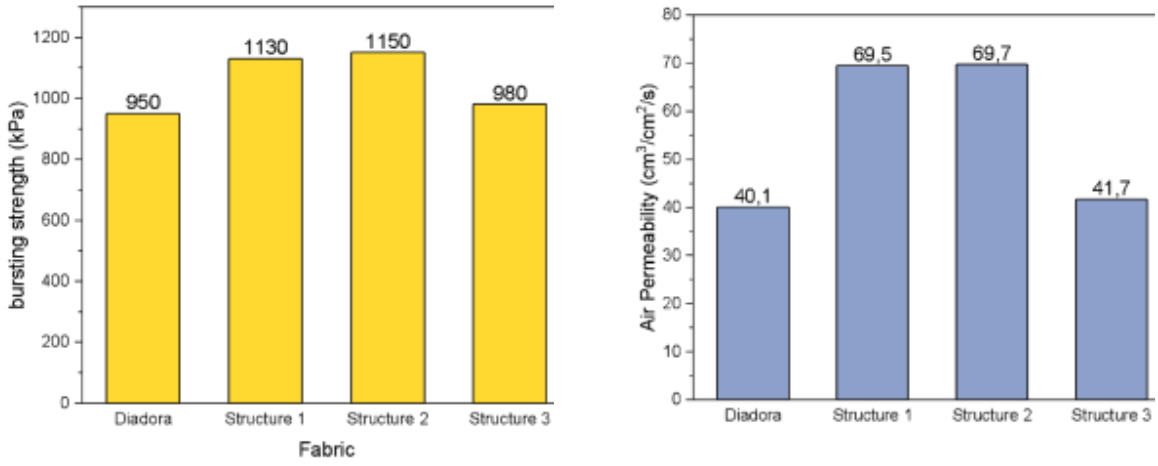
Figure 5. Knit Fabric construction analysis (**a**) CPI dan WPI (**b**) fabric density and thickness

In addition, the knit structure also influences fabric density and thickness. The rib 1x1 knit structure tended to increase the fabric density and thickness. Structure 2 which has one course of Rib 1x1 on each repeating design has less fabric density and thickness than Structure 3 which has two courses of Rib 1x1 on each repeating design. Because of Rib 1x1 knit structure formed a loop on both the needle beds (front and back needle bed), the fabric was denser in the thickness direction. Therefore Structure 3 was the thickest knit fabric and the heaviest in the given area of all three knit structure designs. Although Diadora and Structure 1 has similar knit structure, the materials and yarn size used by Diadora was different. Diadora used TD 649,2 yarn size which has a bigger yarn size than the rest of the knit structure. Furthermore, Diadora was the heaviest compared to the three knit fabrics.

One-way ANOVA was conducted to compare the effect of knitted structure on fabric density and thickness. It revealed that there was a statistically significant difference in mean fabric density between at least two groups (F (2,6) = [99.436], p = 0.000). Similar effect to fabric density, the knitted structure effects on fabric thickness were also statistically significant at p<0.001 (F(2,6) = [778.106], p=0.000). These three knit structure fabrics have likely more lightweight than Diadora. This advantage caused them better at comfort and energy consumption as stated in the study that the 1% increase in weight of shoe weighs causes a 3% - 10% increase in human energy consumption (Jones BH, 1984).

4.2 Bursting Strength and Air Permeability Analysis

The burst strength of the fabric is influenced by several factors, starting from the fabric construction, the thread number, and the structure of the entanglement. According to the raw materials with the same yarn number then CPI x WPI and the different loop formation and knit structure, the fabric properties of burst strength and air permeability can be seen in Figure 6.



(a) (b)

Figure 6. Knit Fabric properties (**a**) Bursting Strength (**b**) air permeability

Both Structure 1 and Structure 2 have better burst strength and air permeability than Structure 3 and Diadora. It was caused by the tubular knit structure which has a loop formation on each

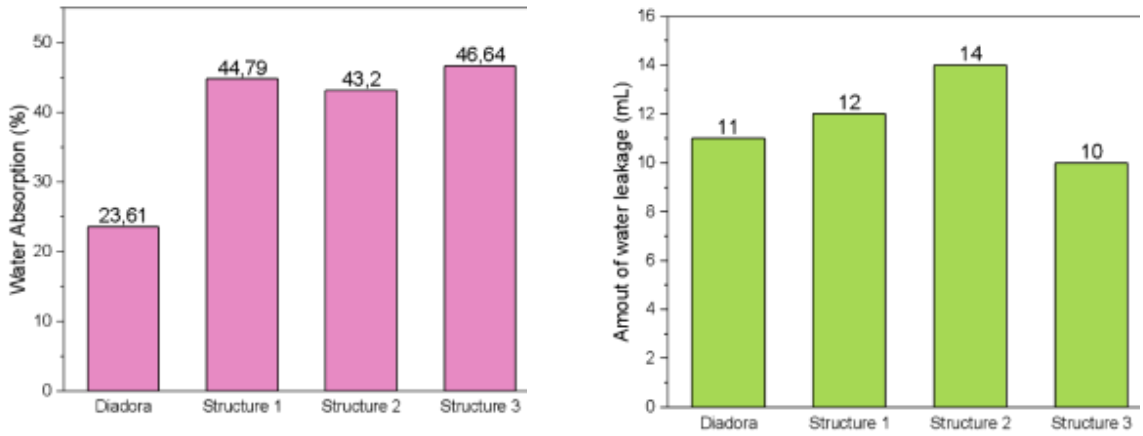
needle bed alternately leading to form a tube knitted fabric. Its form made an air gap between two layers of fabric formation. This gap made better airflow through the fabric.

To compare the effect of knitted structures on the air permeability of knitted fabric, the one-way ANOVA was conducted. It revealed that there was a statistically significant difference in mean air permeability between at least two groups (F (2,27) = [572.448], p = 0.000).

In addition, Structure 1 and Structure 2 have the highest number of loop formations in course direction (CPI). Due to their tight structure, they exhibited higher bursting strength and air permeability (M. E. Ince and H. Yildirim, 2018).

4.3 Water Resistance properties of Knit Fabric Analysis

Leakage is the amount of water in the test tube below the sample stated in ml or cc. The higher the amount of leakage that occurs, the lower the water resistance quality. Water leakage occurs after the absorption of water by the fabric reaches its maximum point. The water absorption and amount of water leakage can be seen in Figure 7.



(a) (b)

Figure 7. Knit Fabric water resistance test result (**a**) water absorption (**b**) amount of water leakage

Structure 3 has the highest water absorption and the smallest water leakage. Because structure 3 is the thickest fabric and the loose fabric compared to the others, water that could penetrate was likely less than the thinner fabric. The increase in the fabric tightness decreases the air permeability and increases the wicking ability, especially in 60 min measurements (E.Oner, A. Okur,2013). Nevertheless, Diadora exhibited the lowest water absorption because of the type of yarn composition. Diadora used polyester and polyurethane yarn which has hydrophobic properties.

5. CONCLUSIONS

The study revealed that knitted structure affected the quality of knitted fabric. For shoe materials, knitted fabric with Structure 3 exhibited closely similar yarn density (CPI and WPI) and bursting strength and air permeability properties to produce existing Diadora 91115 NV Alonzo. While the knit structure design is similar to Diadora 91115 NV Alonzo, Structure 1 which used polyester and cotton yarn with refined yarn size showed better properties in terms of fabric density (more lightweight), bursting strength, air permeability, and water resistance.

Conflicts of Interest: no potential conflict of interest was reported by the author(s).

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