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The Evaluation of the Manufacturing and Functions of Complex Knitted Fabrics

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The Evaluation of the Manufacturing and Functions of Complex Knitted Fabrics

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Abstract

With the development of technology, the electronic communication equipment brings a lot of convenience for human life nowadays. However, the electromagnetic waves have been proven that they may be harmful to human health by many studies; therefore, the electromagnetic shielding and electrostatic protection are necessary. The purpose of this study is in order to reduce the harm of electromagnetic waves on humans. First, stainless steel wires are used as the core and are wrapped in bamboo charcoal yarns. During the process, the wrapped materials are along the S- and Z-direction with different wrapping counts via an electrical covering machine. The purpose is to form stainless steel (SS)/bamboo charcoal (BC) wrapped yarns. The wrapped yarns are then examined for tensile strength and elongation for the optimal parameters. And next, SS/BC wrapped yarns (the wrap material) and spandex fibers (the core) are twisted with different twisting counts and twisting speeds into bi-layer elastic wrapped yarns via a rotor twister. Last, the bi-layer elastic wrapped yarns and BC yarns serve as the face yarns, while antibacterial yarns, cross-section wicking yarns, and spandex fibers are used as the ground yarns. A computer jacquard hose machine is used to form these materials into elastic, functional composite weft knits. The influences of wrap counts on the mechanical properties, EMI SE of the knits are tested in order to make the elastic composite knits with multiple functions. Finally, gain the complex elastic knitted fabric. Then the complex knitted fabrics have permanent anti-static properties and electromagnetic shielding effectiveness. The test results show that complex knitted fabrics have the maximum tensile strength (453.45N) and EMSE (38.3 dB).

Keywords: Complex Knitted Fabric, Electromagnetic Shielding Effectiveness, Functional, Tensile Strength Elongation Test.

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Introduction

People are being concerned about high quality work and leisure activities as a result of advancing technologies shows the symbolic index of a progressing society. People are thus willing to invest money and time to manage their life with a high quality. For example, there are many studies exploring the preparation of functional textiles with an emphasis of providing traditional textiles with multiple functions [1, 2]. Functional textiles have been commonly used, and people desire to wear multi-functional and comfortable garments [3, 4]. Namely, single-functional products no longer satisfy the demands of consumers, and enriching multiple functions to textiles increases the added value [5-7]. In addition, the rapid development of electronic machinery, precise machinery, and petrochemical industries improves the standard of living. It brings convenience but also causes static electrical issues. Electronic facility used in communication and other purposes are likely to create a great number of electromagnetic waves, including the electromagnetic wave radiation caused by the facility and wires as well as the external environment. Without effective static insulation, electromagnetic waves can interfere with the performance of equipment, cause malfunctions, and even afflict the human body with diseases. A long-term exposure to electromagnetic wave radiation jeopardizes the peripheral nervous system, cardiovascular system, temperature adjustment, while decreasing the number of platelets and white blood cells. In order to minimize the negative influences of electromagnetic wave radiation, people start developing and producing electromagnetic shielding textiles, protective clothing, and protective gear [8-11].

In this study, the functional complex knits are composed of SS wires, BC yarns, wicking yarns, antimicrobial yarns, and spandex yarns. The SS/BC wrapped yarns are made using an electrical covering machine, after which the spandex fibers are added to form bi-layered functional yarns, which highly improves the maximum tensile strength and elongation. Comparing to pure SS wires, the bi-layered functional yarns are much mechanically stronger, and can reinforce the structure of functional complex knits. The SS wires used in this study have seven major functions, including electromagnetic shielding effectiveness (EMSE), anti-static electricity, electrical conductivity, heat resistance, cut resistance, and abrasion resistance. The resulting complex knits have EMSE of 20 dB, which is a qualified EMSE candidate for everyday necessities [12].

Experimental

Materials

Stainless steel (SS) wires (#316, Yuen Neng, Taiwan) have a diameter of 50μm (0.05 mm). Bamboo charcoal (BC) yarns (Hua Mao Nano-Tech, Taiwan) have a specification of 70 D/48f. Spandex wires (DuPont, US) have a fineness of 70 denier (P) and 144 denier (P*). Wicking (W) yarns (Everest Textile, Taiwan) have a specification of 75D/72f. Antibacterial yarns (zinc oxide series, Tung Ho Textile, Taiwan) (Z) have a fineness of 75D.

Preparation of SS/BC/Spandex Bi-Layered Wrapped Yarns

The optimal SS/BC wrapped yarns are obtained from a previous study [13]. Stainless steel (SS) wires are used as the core and bamboo charcoal (BC) nylon filaments are used as the sheath. The sheaths wrap the core along the S- and Z-direction at different wrapping counts (11, 12, 13, 14, and 15 turns/cm) using an electrical covering machine, forming SS/BC wrapped yarns. The wrapped yarns are tested for tensile elongation at break, determining that the optimal wrapping counts are 11, 12, and 13 turns/cm.

The three wrapped yarns are then separately twisted with 70 D spandex (P) elastic yarns (i.e. the core) at twisting counts of 1, 2, and 3 twists/cm using a rotary twisting machine. The second process forms the bi-layer SS/BC/Spandex (P) wrapped yarns, and the wrapped yarns exhibit the maximum tensile strength and elongation at break when the optimal twisting counts of 1 and 2 twists/cm are used [13]. Therefore, the optimal six groups of wrapped yarns are used to make functional complex knits, after which the physical properties of the knits are evaluated.

Fabrication of Functional Complex Knits

The optimal bi-layered wrapped yarns are made of the six combinations of wrapping counts of 11, 12, and 13 turns/cm and twisting counts of 1 and 2 twists/cm. The bi-layered wrapped yarns and four BC nylon yarns are used as the face yarns. Two wicking yarns, one antibacterial yarn, and one 144 D spandex yarns are used as the ground yarns. A computer jacquard hose machine (DK-B318, Da Kong, Taiwan) is used to weft-knit the surface and ground yarns into complex knits that have functions of EMSE, thermal insulation, perspiration absorbent and moisture exhaling properties, antibacterial efficacy, and elasticity. The functional complex knits are denoted as SB11/P1/B-WZP*, SB11/P2/B-WZP*, SB12/P1/B-WZP*, SB12/P2/B-WZP*, SB13/P1/B-WZP*, and SB13/P2/B-WZP*, indicating the bi-layered wrapped yarns and other constituent yarns. For example, SB11/P1/B-WZP* where SB11 means SS/BC wrapped yarns made at wrapping counts of 11 turns/cm, P1 means the addition of 70 D spandex fibers at a twisting counts of 1 twist/cm, and B-WZP* means four “bamboo charcoal nylon yarns and two “wicking yarns, one “zinc oxide antibacterial yarn, and one 144 D spandex yarn.

Tests

Tensile Strength and Elongation Tests

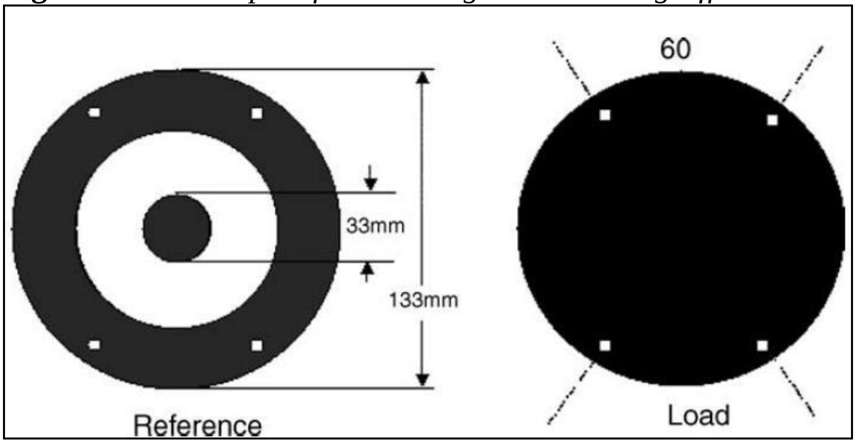
The functional complex knits are tested for their tensile strength and elongation at break using a universal testing machine (HT-9101, Hung Ta

Instrument, Taiwan) as specified in CNS13752 L3243. The grips are 10 mm apart, and the tensile speed is 300 mm/min. The samples are sized as 25 mm × 200 mm. Samples are taken along the warp direction and the weft direction, respectively. Five samples for each specification are used. The mean of values for each group is recorded.

Measurement of Electromagnetic Shielding Effectiveness (EMSE)

The testing system of electromagnetic shielding effectiveness involves electromagnetic shielding effectiveness test sample holder (EM-2107A, E-Instrument, US) with incident frequencies between 300k and 3G Hz and an electromagnetic field of a far-field plane wave as specified in ASTM D-4935. The standard test sample is as shown in Figure 1. A hollow test lamination (Washer Type) with the same thickness is used as the reference, and its EMSE (SERef) is measured in order to calibrate this measuring device. The experimental groups are the single-layered and double-layered functional complex knits.

Figure 1. *Test Sample of Electromagnetic Shielding Effectiveness*

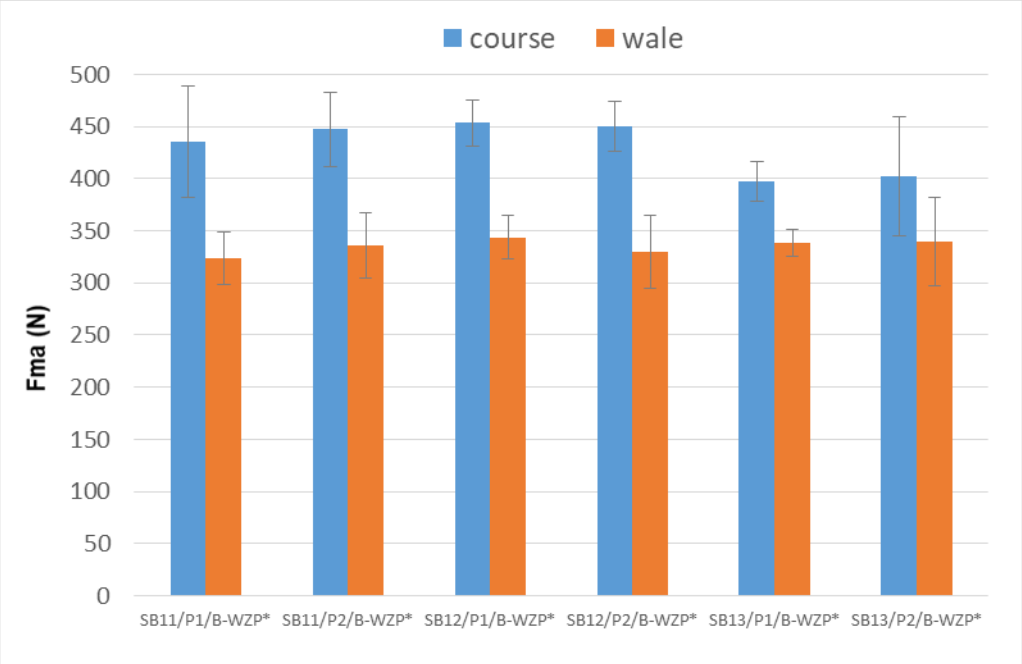


Results and Discussion

Effect of Wrapping/Twisting Counts on the Tensile Strength at Break of Functional Complex Knits

Figure 2 shows that the SB12/P1/B-WZP* has the optimal tensile strength along the warp direction of 453.45N and the optimal tensile strength along the weft direction of 343.69 N. The second highest tensile strength along the warp direction is 449.742 N for SB12/P2/B-WZP*, and the second highest tensile strength along the weft direction is 339.762 N for SB13/P2/B-WZP*. When the wrapping counts is 12 turns/cm, the SS/BC wrapped yarns have the greatest mechanical strength, which in turn provides the resulting functional complex knits with the highest tensile strength. As the functional complex knits are weft-knitted, the yarns are fed into the computer jacquard hose machine along the weft direction and formed into loops that are interlocked, and the functional complex knits have greater tensile strength along the warp direction than that along the weft direction.

Figure 2. *The Maximum Tensile Strength of Functional Complex Knits*

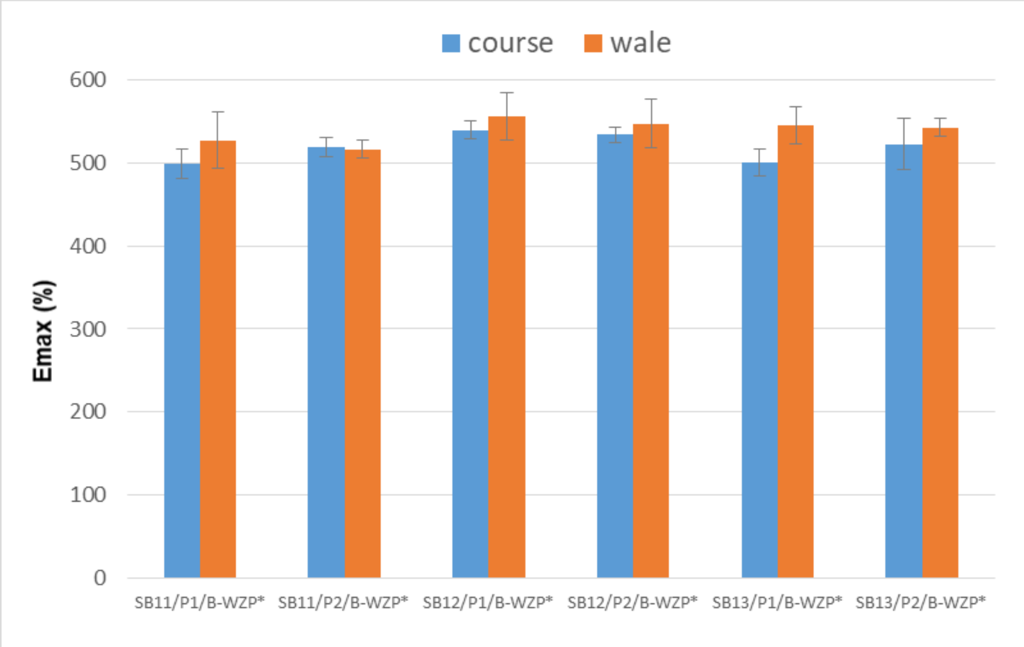


The bi-layered wrapped yarns are made of wrapping counts of 11, 12, and 13 turns/cm and twisting counts of 1 and 2 twists/cm.

Effect of Wrapping/Twisting Counts on the Elongation at Break of Functional Complex Knits

Figure 3 shows that the SB12/P1/B-WZP* has the optimal elongation at break along the warp direction of 539.614% and the optimal elongation at break along the weft direction of 555.23%. The second highest elongation at break along the warp direction is 547.422% for SB12/P2/B-WZP* and the second highest elongation at break along the weft direction is 339.762% for SB13/P2/B-WZP*. When the wrapping counts is 12 turns/cm, the S/B wrapped yarns have the greatest mechanical strength, which in turn provides the resulting functional complex knits with the highest tensile strength. As the functional complex knits are weft-knitted, the yarns are fed into the computer jacquard hose machine and are formed into loops that are interlocked. When they are stretched along the weft direction, the loops become linear and the functional complex knits have greater elongation at break along the weft direction.

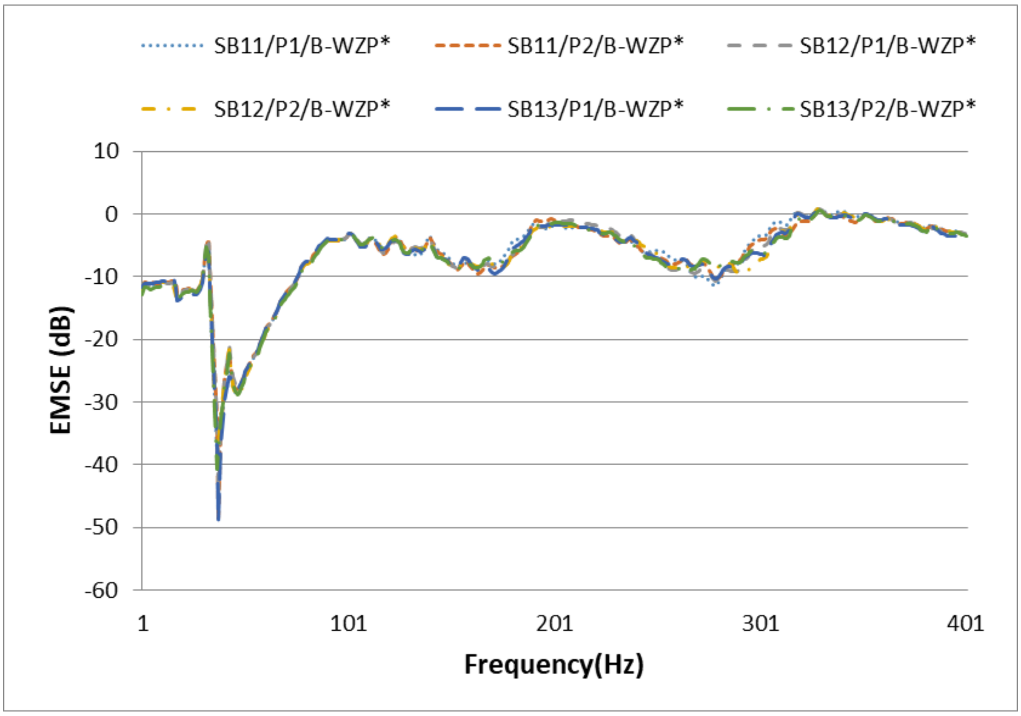
Figure 3. *Elongation at Break of Functional Complex Knits*



The bi-layered wrapped yarns are made of wrapping counts of 11, 12, and 13 turns/cm and twisting counts of 1 and 2 twists/cm.

Effect of Wrapping/Twisting Counts on the EMSE along the Warp Direction of Functional Complex Knits

Figure 4. *EMSE along the Warp Direction of Functional Complex Knits*



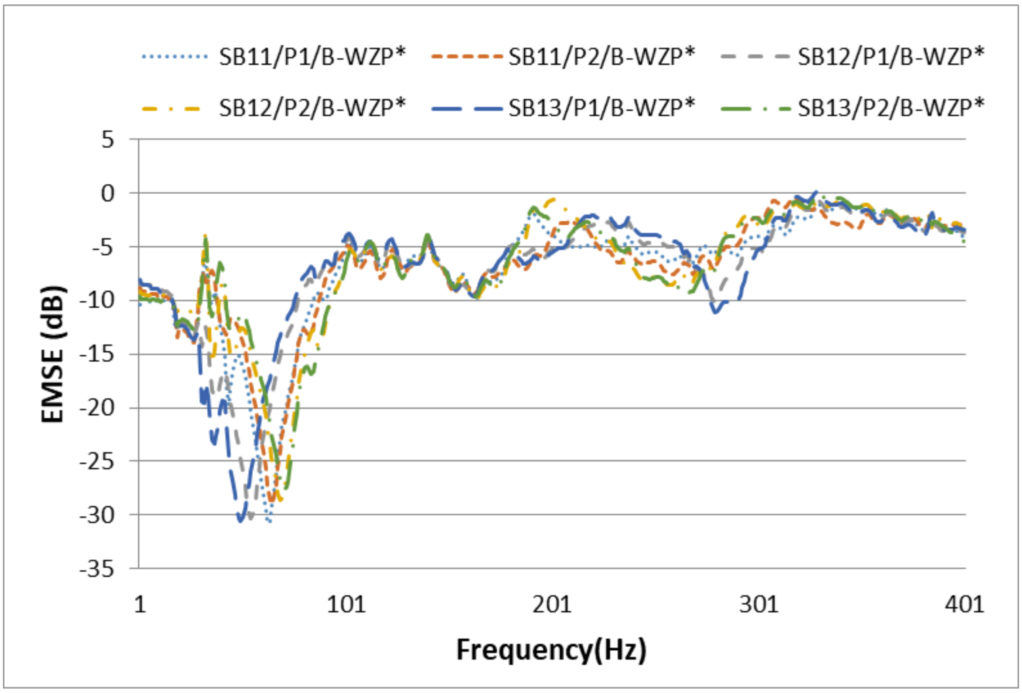
The bi-layered wrapped yarns are made of wrapping counts of 11, 12, and 13 turns/cm and twisting counts of 1 and 2 twists/cm.

Figure 4 shows that the increasing wrapping counts have a positive influence on the EMSE along the warp direction of the functional complex knits at low frequencies. In particular, SB13/P1/B-WZP* has the highest EMSE along the warp direction of 49.19 dB at 278 MHz, followed by SB12/P1/B-WZP* whose EMSE along the warp direction is 48.62 dB at 278 MHz. There is no significant difference in the wrapping counts of S/B wrapped yarns. As a result, all of the functional complex knits are composed of similar amounts of stainless steel wires, and their EMSE is comparable regardless of the wrapping counts.

Effect of Wrapping/Twisting Counts on the EMSE along the Weft Direction of Functional Complex Knits

Figure 5 shows the EMSE along the weft direction of the functional complex knits. Increasing the wrapping counts improves the EMSE marginally and the functional complex knits also have greater average EMSE along the weft direction at low frequencies. In particular, SB13/P1/B-WZP* has the highest EMSE along the weft direction of 30.6 dB at 368 MHz, followed by SB12/P1/B-WZP* which has EMSE along the weft direction of 30.28 dB at 405 MHz. Due to the higher elongation at break along the weft direction, the functional complex knits have greater EMSE along the weft direction.

Figure 5. *EMSE along the Weft Direction of Functional Complex Knits*

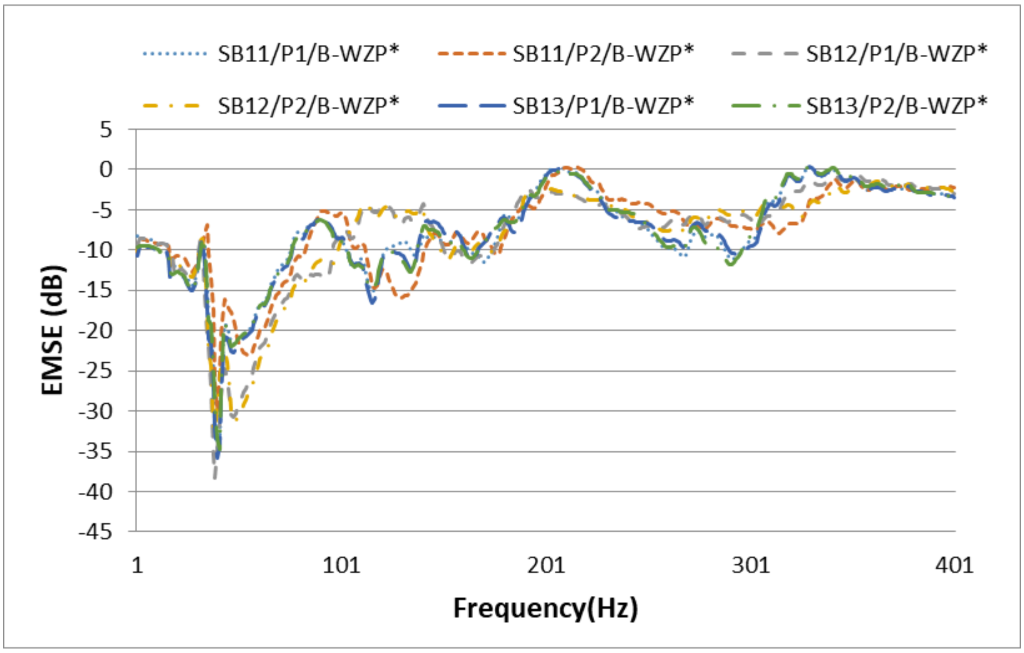


The bi-layered wrapped yarns are made of wrapping counts of 11, 12, and 13 turns/cm and twisting counts of 1 and 2 twists/cm.

Effect of Wrapping/Twisting Counts on the EMSE along the Warp Direction of Double-Layered Functional Complex Knits

Figure 6 shows that the increasing wrapping counts have a positive influence on the EMSE along the warp direction of the double-layered functional complex knits at low frequencies. In particular, double-layered SB12/P1/B-WZP* has the highest EMSE along the warp direction of 38.3 dB at 285 MHz, followed by double-layered SB13/P1/B-WZP* whose EMSE along the warp direction is 35.83 dB at 293 MHz. The increase in number of laminates renders higher EMSE, and double-layered functional complex knits are composed of more stainless steel wires. The conductive network in the interior is denser, indicating that there are more electrical circuits per unit area, which results in an increasing tendency of the EMSE.

Figure 6. *EMSE along the Warp Direction of Double-layered Functional Complex Knits*

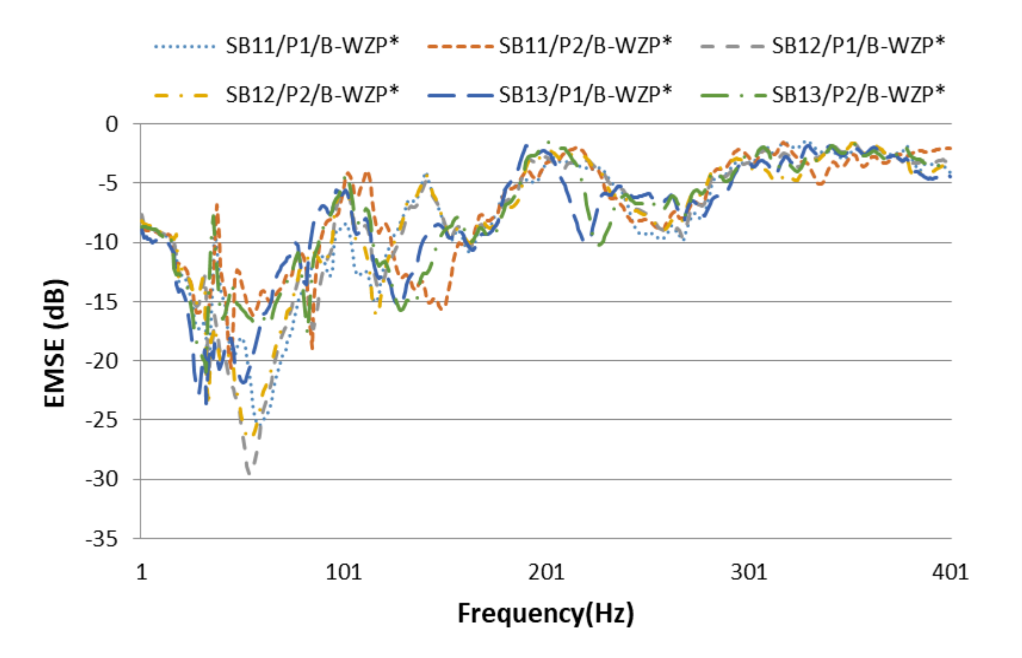


The bi-layered wrapped yarns are made of wrapping counts of 11, 12, and 13 turns/cm and twisting counts of 1 and 2 twists/cm.

Effect of Wrapping/Twisting Counts on the EMSE along the Weft Direction of Double-Layered Functional Complex Knits

Figure 7 shows the EMSE along the weft direction of the double-layered functional complex knits. Increasing the wrapping counts provides the functional complex knits with more stainless steel wires and greater average EMSE at low frequencies. In particular, double-layered SB12/P1/B-WZP* has the highest EMSE along the weft direction of 29.6 dB at 405 MHz, followed by double-layered SB12/P2/B-WZP* which has EMSE along the weft direction of 26.62 dB at 405 MHz. Figures 6 and 7 show that more laminates are helpful with EMSE due to a denser conductive network composed of S/B wrapped yarns; the more the laminates, the more the electrical circuits per unit area. Therefore, the double-layered functional complex knits are effective in shielding electromagnetic waves.

Figure 7. *EMSE along the Weft Direction of Double-layered Functional Complex Knits*



The bi-layered wrapped yarns are made of wrapping counts of 11, 12, and 13 turns/cm and twisting counts of 1 and 2 twists/cm.

Conclusions

This study successfully produces multiple functional complex knits with functional wrapped yarns. Increasing the wrapping counts provides SB12/P1/B-WZP* with maximum tensile strength of 453.45 N for the warp direction and 343.69 N for the weft direction as well as the maximum elongation at break of 539.614% for the warp direction and 555.23% for the weft direction. The functional complex knits also have better EMSE at low frequencies. SB13/P1/B-WZP* has the highest EMSE along the warp direction of 49.19 dB at 278 MHz, a shielding level of 99.99%. It also has the maximum EMSE along the weft direction of 30.dB. Double-layered functional complex knits also have higher EMSE at low frequencies and have the optimal EMSE of 38.3 dB at 285 MHz along the warp direction and 29.6 dB at 405 MHz along the weft direction. The test results show that the functional complex knits have greater EMSE along the warp direction; moreover, EMSE of double-layered functional complex knits is higher than that of the single-layered ones. Regardless of whether the number of laminates, all of the functional complex knits have EMSE of above 20dB which is qualified to be used as standard EMSE commodities. The double-layered functional complex knits have maximum EMSE that is slightly lower than that of single-layered ones, which is 49.19 dB, a highly efficient shielding rate of 99.99%. The optimal parameters of functional complex knits could be used for further studies that develop safety appliance.

References

[1] Gries T., Veit D. and Wulfhorst B. Textile Technology. In: Gries T., Veit D. and Wulfhorst B., (eds.) Textile Technology (Second Edition). Hanser, 2015, p. I-XVIII.

[2] Waqar S., Wang L. and John S. 9 - Piezoelectric energy harvesting from intelligent textiles. In: Dias T., (ed.) Electronic Textiles. Oxford: Woodhead Publishing, 2015, p. 173-97.

[3] Sampath M. B., Arputharaj A., Senthilkumar M., et al. Analysis of thermal comfort characteristics of moisture management finished knitted fabrics made from different yarns. J Ind Textil 42 (2011) 19-33.

[4] Snezana B. Stankovic, Dusan Popovic, Goran B. Poparic. Thermal properties of textile fabrics made of natural and regenerated cellulose fibers Polymer Testing sci 27 (2008) 41-48.

[5] Özkan E. T. and Meriç B. Thermophysiological comfort properties of different knitted fabrics used in cycling clothes. Textile Research Journal. 2014.

[6] MB S., Aruputharaj A., Mani S. and G. N. Analysis of thermal comfort characteristics of moisture management finished knitted fabrics made from different yarns. Journal of Industrial Textiles. 2011.

[7] Yanılmaz M. and Kalaoğlu F. Investigation of wicking, wetting and drying properties of acrylic knitted fabrics. Textile Research Journal. 2012; 82: 820-31.

[8] Goldsmith J. R. Epidemiologic evidence relevant to radar (microwave) effects. Environ Health Perspect; 105 Suppl 6:1579-87 (1997).

[9] Hyland G. J. Physics and biology of mobile telephony. Lancet; 356:1 833-6 (2000).

[10] L. M. Green, A. B. Miller, P. J. Villeneuve, D. A. Agnew, M. L. Greenberg, J. H. Li, and K. E. Don – nelly. A case-control study of childhood leukemia in Southem Ontario, Canada, and exposure to magnetic fields in residences, International Journal of Cancer 82, 161-170 (1999).

[11] R. W. Habash. Electromagnetic the uncertain health risks, IEEE, 22, 23-26 (2003).

[12] Repacholi M. H. Low-level exposure to radiofrequency Electromagnetic fields: health effects and research needs. Bioelectromagnetics 98; 19: 1-19.

[13] C. M. Lin, P. C. Hsiao. Physical Properties and Manufacturing Process Evaluation of Complex Stainless Steel Wire/Bamboo Charcoal Nylon/Spandex Piled Yarn and Knitted Fabric, ATC-13, Australia, 2015.11, p. 877-880.