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A Simulation Model of Twist Influenced by Fibre Movement inside Yarn on Solenoid Coordinate

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Abstract

In textile science, spinning is a process to make a yarn from a natural material (cotton) or synthetic. In textile, to produce a yarn, it can be made and produced by OE rotor spinning machine. The quality of yarn can be determined by the twist, yarn count number, the strength of yarn, hairiness etc. In this research, it has been found the formula to relate the yarn count number in metric count (N_m) to the twist. Based on this research, twist has been determined and formulated by analyzing the movement of fibre inside yarn using tensor calculus on solenoid coordinate.

Keywords: Yarn Twist, Solenoid Coordinate, Tensor Calculus

Introduction

During the spinning process, fibres are continuously fed into the OE rotor machine, while the yarn is simultaneously taken up. Due to the rotor speed , the yarn m_r is always taken up under tension caused by the centrifugal force. In the process of making yarn, there are some variable to determine yarn count such as: twist T defined as the turn of fibre per length, $F_{take-off} = F_0$ defined the tension in the take-off nozzle inside rotor, α as the angle of twist. The study of the fibre movement inside yarn and the influenced of it have been researched of many researchers. According to Rohlena [1], Lawrence [2] and Hearle [3] Twist can be also defined as the ratio of rotor angular velocity of rotor to delivery yarn velocity. Lawrence [2] and Hearle [3] defined twist as the ratio of $\tan\alpha$ to πd_{yarn} .

Fibre migration is the change in the distance of a fibre (along its length) from the axis of a yarn, which occurs during production of the open end spinning yarn (OE yarn). According to Lawrence[2], the characteristic of spun yarn can be determined by the fibre movement and yarn structure as **Fig.1** below.

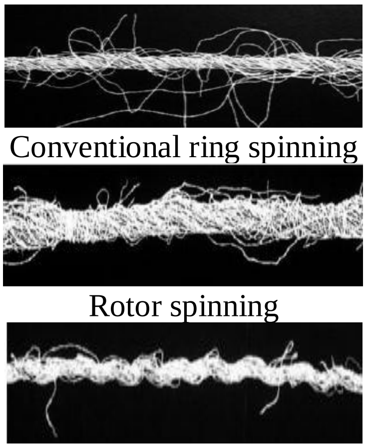

Figure1: Structure of Yarn Based on Machine Characteristic

According to Hearle experiment, the strength of yarn is influenced by the rate of twist and the relation is shown as the lower of twist, the higher of the strength of yarn per tex and vice versa. Rohlena [1] said that breakage rate is influenced by the twist. The lower the twist, the lower the breakage rate. According to Musa [4], Penava [5] and Prendzova [6], the strength of yarn and yarn count number are influenced by the yarn diameter. Musa [4] said that The wider yarn diameter, the stronger the strength of yarn. Furter [7] and Trommer [8] have formulated the relationship of twist to the yarn count number in metric count as equation (1) which is related by twist multiplier a_m. Rohlena [1] and Hearle [3] formulated yarn twist as a function of yarn count number as equation (2)

$$T = a_m \sqrt{N_m} \tag{1}$$

$$T = \left(\frac{tgn\alpha}{2} \sqrt{\rho} \right) \sqrt{N_m} = a_m \sqrt{N_m} \tag{2}$$

According to all researchers [9, 10], yarn twist will influence the quality of yarn as strength of yarn and yarn count number. in this research, it will discuss and formulate the relationship of yarn twist to yarn count number by looking the movement of fibre inside yarn using solenoid coordinate. In this research, tensor calculus has a main role to solve the movement of fibre inside yarn and to get the relationship.

Fibre Movement on Solenoid Coordinate

Fibre movement on solenoid coordinate can be formulated using a calculus tensor. By knowing the coordinate system, the solid materialequation inside yarn can be analyzed [11,12,13,14,15]. In particular A fibre, with a mass $m,$ moves inside a yarn. The position of fibre can be determined by $d\varphi$ and $d\phi$. The rotor influenced the yarn rotation measured as $n_r = \dot{\varphi}$. The yarn delivery speed is determined by the $v_d = \dot{\phi}r$. The fibre moves along the yarn during a timedt. A yarn is assumedto be formed as solenoid coordinate whose radius is $a = r$ and the length of gap b can be shown as **Fig.2** below. Consider as a transformation from rectangular coordinates to solenoid coordinates as below

$$l = (x, y, z) = ((b + a\cos\phi)\cos\varphi, (b + a\cos\phi)\sin\varphi, c\varphi + a\sin\phi) \quad (3)$$

Using equation (3), it can be predicted the yarn movement equation using geodesic equation and be simulated by Matlab.

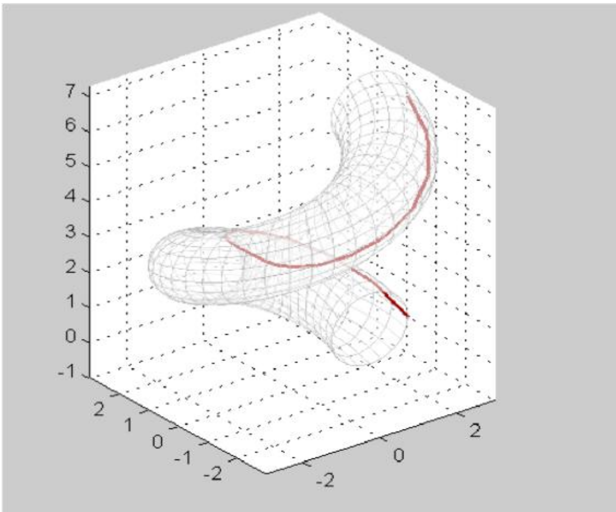

Figure2: Fibre Movement on Solenoid Coordinate

Consider the yarn is assumed to be circular in cross section and the radius of yarn is constant. The fibre is rotated with angular velocity $\dot{\varphi}$ and moves parallel to the yarn lengthby angular speed $\dot{\phi} = \dot{v}$. The square of the line element on solenoid coordinate can be shown as

$$dl^2 = [(b + a\cos\phi)^2 + c^2]d\varphi^2 + +2ca\cos\phi d\phi d\varphi + a^2 d\phi^2) \quad (4)$$

The metric elements can be identified as

$$g_{mn} = \begin{pmatrix} (b + acos\phi)^2 + c^2 & ca\cos\phi \\ ca\cos\phi & a^2 \end{pmatrix} \quad (5)$$

The geodesic equation of solenoid for $\dot{\phi}$and $\dot{\varphi}$ and for $c = a$can be written as

$$\frac{d^2x^1}{dt^2} + \Gamma^1_{mn}\frac{dx^m}{dt}\frac{dx^n}{dt} = \ddot{\varphi} + \frac{a sin\phi \cos\phi\,(b + a\,cos\phi)}{(a^2 + 2abcos\phi + b^2)}\dot{\varphi}^2 - 2\frac{(b + a\cos\phi)a\sin\phi}{a^2 + 2abcos\phi + b^2}\dot{\phi}\dot{\varphi} - \frac{a^2 sin\,\phi}{a^2 + 2abcos\phi + b^2}\dot{\phi}^2 \quad (6)$$

$$\frac{d^2x^2}{dt^2} + \Gamma^2_{11}\left(\frac{dx^1}{dt}\right)^2 + 2\Gamma^2_{12}\frac{dx^1}{dt}\frac{dx^2}{dt} + \Gamma^2_{22}\left(\frac{dx^2}{dt}\right)^2 = \ddot{\phi} + \left[\frac{[b^2 + 2abcos\phi + a^2(cos^2\phi + 1)]((b + a\cos\phi)a\sin\phi)}{a^2 + 2abcos\phi + b^2}\right]\dot{\varphi}^2 + 2\left[\frac{(b + a\cos\phi)a\,cos\phi\,\sin\phi}{a^2 + 2abcos\phi + b^2}\right]\dot{\phi}\dot{\varphi} \quad (7)$$

By using equation (6) it can be assumed that there's an external force as a force in take-off rotor occurred by the machine $F_{take-off} = F_o$.Trommer [8] has found that $n_r \approx \frac{n_d}{2}$ or $\dot{\varphi} \approx \frac{\dot{v}}{2}$, then

$$\left\{\frac{(b + a\cos v)a/b^2\sin v}{1 + 2\frac{a}{b}cosv + \frac{a^2}{b^2}} + \frac{a^2/b^2 sin\,v}{1 + 2\frac{a}{b}cosv + \frac{a^2}{b^2}} - \frac{a/b^2 sinv\cos v\,(b + a\,cosv)}{4\left(1 + 2\frac{a}{b}cosv + \frac{a^2}{b^2}\right)}\right\}\dot{v}^2 = \frac{F_{take-off}}{mr} \quad (8)$$

$$\left\{\frac{(b + a\cos v)a/b^2\sin v}{1 + 2\frac{a}{b}cosv + \frac{a^2}{b^2}}\left(1 - \frac{\cos v}{4}\right) + \frac{a^2/b^2 sin\,v}{1 + 2\frac{a}{b}cosv + \frac{a^2}{b^2}}\right\}mr\dot{v}^2 = F_{take-off} \quad (9)$$

If the radius of yarn $r = a = c$, then

$$\left\{\frac{(b + a\cos v)\sin v}{\left(\left(1 + 2\frac{a}{b}cosv + \frac{a^2}{b^2}\right)\right)}\left(1 - \frac{\cos v}{4}\right) + \frac{asin\ v}{1 + 2\frac{a}{b}cosv + \frac{a^2}{b^2}}\right\}\frac{c^2}{b^2}m\dot{v}^2 = F_{take-off} \quad (10)$$

Assumed that $sin\alpha = c/b$, then

$$\left\{\frac{(b + a\cos v)\sin v}{\left(\left(1 + 2\frac{a}{b}cosv + \frac{a^2}{b^2}\right)\right)}\left(1 - \frac{\cos v}{4}\right) + \frac{asin\ v}{1 + 2\frac{a}{b}cosv + \frac{a^2}{b^2}}\right\}sin^2\alpha\ m\dot{v}^2 = F_{take-off} \quad (11)$$

For the gap $b \gg a$ then

$$\left\{\frac{(b + a\cos v)}{\left(\left(1 + 2\frac{a}{b}cosv + \frac{a^2}{b^2}\right)\right)}\left(1 - \frac{\cos v}{4}\right) + \frac{a}{1 + 2\frac{a}{b}cosv + \frac{a^2}{b^2}}\right\}\sin v\, sin^2\alpha\ m\omega^2 \approx F_{take-off} \quad (12)$$

$$\left\{b\left(1 - \frac{\cos v}{4}\right)\right\}sinv\, msin^2\alpha\ \omega^2 = F_{take-off} \quad (13)$$

$$\frac{mh}{2}sin^2\alpha_{max}\ \omega^2 = F_{take-off} \quad (14)$$

$$sin\alpha_{max} \approx tan\alpha_{max} \approx 1{,}4\frac{\sqrt{F_{take-off}}}{\omega h}\sqrt{N_m} = 0{,}7\frac{\sqrt{F_o}}{n_d\pi h}\sqrt{N_m} = 0{,}7\frac{\sqrt{F_o}}{n_r\pi H}\sqrt{N_m} \quad (15)$$

According to Hearle[1], twist is defined as

$$T = \frac{\tan\alpha}{\pi d_{yarn}} \quad (16)$$

$$T = \left(\frac{0{,}7\sqrt{F_{take-off}}}{n_r\pi^2 d_{yarn}H}\right)\sqrt{N_m} \quad (17)$$

Using equation (17) it can be drawn the relationship of twist and yarn count in metric as **Fig.3** below

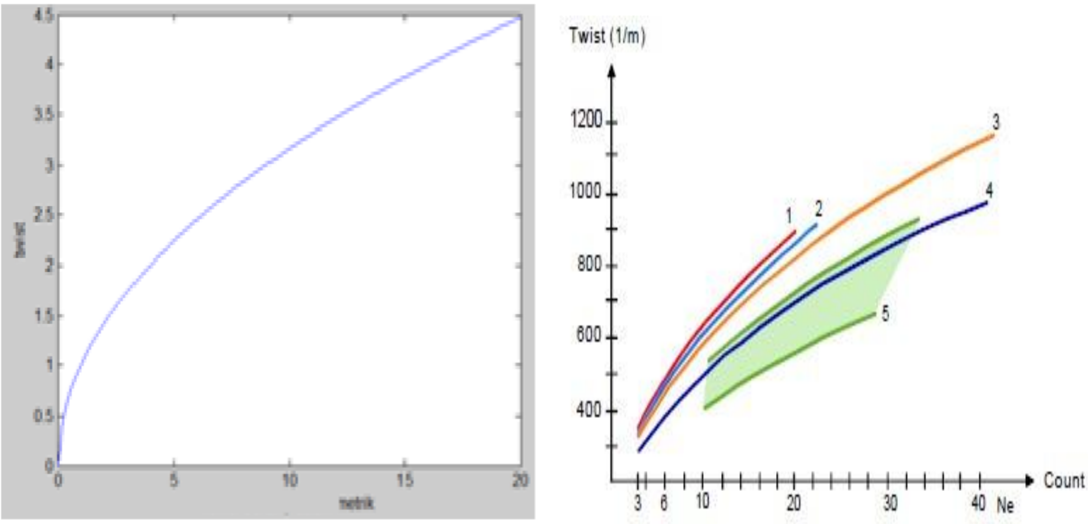

Figure3: Relationship of Twist and Yarn Count in Metric
(Model and Furter's Experiment)

Experiment Result

According to the experiment result in Industry by following data below (**Table**-1 and **Table-2**)

Table1: Experimental Result in Industry

rotor speed (rpm)	a_e	a_m	N_e	N_m	v_d *(m/min)*	*T (tpm)*	$\mathcal{H}$ */m*
72000	4.47	135.454545	39.37	66.72881	64.27273	1119.75	3.46
72000	4.5	136.363636	49	83.05085	57.27273	1256.54	2.25
72000	4.5	136.363636	58.84	99.72881	52.18182	1379.31	2.13

Table2: Experimental Result in Industry

Tt(tex)	v_d*(yard/min)*	*Strength (cN)*	$\mathcal{H}$*/100yds*
14,98	70.7	237	315
12,04	63	186	205
10,10	57.4	149	194

by using Table-1 and Table-2 above, it can be made the relationship of Twist and Yarn Count in metric N_m as shown in **Fig.4** below

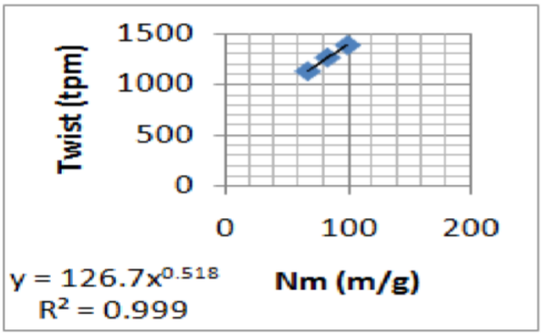

Figure4: Relationship of Twist and Yarn Count in Metric

To measure the twist multiplier a_m, it can be used the equation (17). The result of twist multiplier a_m can be seen in equation (18) – equation (20) below

$$T = \left(0{,}7\frac{\sqrt{F_{take-off}}}{n_r\pi^2 d_{yarn}H}\right)\sqrt{N_m} = \left(0{,}7\frac{\sqrt{R_{take-off}T_t}}{n_r\pi^2 d_{yarn}d}\right)\sqrt{N_m} = a_m\sqrt{N_m} \quad (18)$$

$$a_m = \left(0{,}7\frac{\sqrt{1{,}2.10^{-2}(N/tex).10{,}10(tex)(kg.m/s^2)}}{0{,}72.10^6.0{,}1.10^{-6}40(m^2/\min)}\right) \quad (19)$$

$$a_m \approx 1{,}36.10^2[g^{1/2}\,m^{-3/2}] \quad (20)$$

The magnitude of twist can be measured by the equation (18) and using equation (20), it can be found that the twist

$$T = a_m\sqrt{N_m} = 136\sqrt{99.7} \approx 1{,}36.10^3 m^{-1} \quad (21)$$

Based on the experimental result, the value of twist is 1379 m^{-1}

Results and Discussion

The prediction of fibre movement which moves inside of yarn has been derived using solenoid coordinate occurred on rotor open end spinning machine. In this new theory, the relationship of yarn count number, yarn diameter and the angle of twist related by the strength of yarn take off have been found.

The model in this prediction has shown the relationship of yarn count number to twist of yarn as equation (17). Furter[7] said that the higher the yarn count, the higher the twist *T*. According to Musa [4], Penava [5] and Prenzova [6] the relationship of yarn strength is proportional to the diameter of yarn. The wider the diameter of the yarn the higher the strength of the yarn.

According to Hearle [3], the strength of yarn is influenced by the rate of twist and the relation is shown as the lower of twist, the higher of the strength of yarn. In this research it has been found that the wider diameter of yarn, the lower the twist (shown by the equation. The lower the twist, the higher the strength of yarn.

Conclusion

Fiber movement on yarn has been analyzed to showand to predict the relationship of yarn count in metric to yarn twist. In this research it has beenfound that yarn twistis influenced by yarn count number in metric on solenoid coordinate.It has been found that the formula to relate the relationship is $T=\left(\frac{0,7\sqrt{F_{take-off}}}{n_r\pi^2 d_{yarn}H}\right)\sqrt{N_m}$

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References

[1] Rohlena, V., 1975 *Open-End Spinning*, Elseiver Scientific Publishing Company, New York.
[2] Lawrence, 2003, *Fundamentals of Spun Yarn Technology*, CRC Press, New York.
[3] Hearle & Grosberg, 1969, *Structural Mechanics of Fibres, Yarns and Fabrics*, Wiley-Interscience, New York.
[4] Musa & Ayse, 2006, *Relationships Between Yarn Diameter / Diameter Variation and Strength*, *Fibres & Textiles Journal*, Vol. 14, No. 5, page 84-87.
[5] Penava, 1997*, Analysis of the Coincidence between Thin Places and Breaking Points in a Yarn*, Journal of the Textile Institute,, Vol 88, page. 21-32.
[6] Prend*žova*, 2000*, The Effect of Cotton Yarn Properties on Yarn End Breakage*. International Journal of Polymeric Materials,*, 47*, page. 701-707.
[7] Furter, 2009, *Measurement and significance of yarn twist*, Uster Technology AG, Switzerland.
[8] Trommer, G., 1995 *Rotor Spinning*, Deutscher fachverlag, Frankfurt.
[9] Zeidman, Shawney and Herington, 2003, *Fiber Migration Theory of Ring Spun Yarn*, Indian Journal of Fibre and Textile Research, Vol 28., Page. 123133.
[10] Zhang, Xuefeng and Yonglan, 2011, *Mechanical Properties of Ring-spun Yarn and Its Strength Prediction Model*, Fibres & Textiles Journal, No. 3, Vol. 19, Page. 17-20.
[11] Waner, 2005, *Introduction to Differential Geometry & General Relativity*, Department of Mathematics and Physics, Hofstra University, New York.
[12] Weinberg, 1971, *Gravitation and Cosmology: Principles and Application of The general Theory of Relativity*, John Wiley & Sons Inc, New York.
[13] Martin, 2005, *Elasticity Theory, Applications and Numeric*, Elseiver, Oxford.
[14] Margenau, H., 1956, *The Mathematics of Physics and Chemistry,* East-West Press Private Ltd. New Delhi.
[15] Moore, E.N., 1934, *Theoretical Mechanics*, John Wiley &Sons, New York.