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Quasistatic model for two-strand yarn spinning

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Abstract

A theoretical model underlying a two-strand spinning system is given. Based on the force balance and dynamics characters of the system (mass conservation, energy conservation, and momentum conservation), this system of the equations governing the quasistatic two-strand yarn spinning is self-contained, so that the convergence point can be determined with ease for different inlet velocities, densities, sizes (diameters) of the two strands.

Keywords: Two-strand yarn spinning; Sirospun yarns; Dynamical model

1. Introduction

Two-strand yarn spinning (Sirospun yarns) is conducted on a conventional ring frame by feeding two rovings, drafted simultaneously, into the apron zone at a predetermined separation. Emerging from the nip point of the front rollers, the two strands are twisted together to form a two-ply structure (Cheng and Sun, 1998). Since the new spinning process was invented by the Division of Textile Industry laboratories of the Commonwealth Scientific International Research Organization (CSIRO) in Australia around 1975–1976 (Cheng and Sun, 1998), the two-strand spun or Sirospun yarns have now been widely applied in the worsted industry, for they have a texturized structure in improving the bulk of the parent yarn with desirable properties. For example, the weaveability of the yarn is improved over its counterpart yarns. Meanwhile, many researches and investigations have been made in attempt to understand the underline physics involved in the process and the effects of related important variables. Hawary (1984), Dhawan and Prakash (1987) studied the effects of varying the strand spacing and twist factor on cotton Sirospun yarns; Hawary

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(1984) researched the influence of the center roving guides; Sun and Cheng (2000) investigated the longitudinal and cross-sectional shapes of Sirospun yarns both single and two-plied. Miao et al. (1993) studied the influence of machine variables on the two-strand yarn spinning geometry. However, all the aforementioned researches and investigations are the experimental nature. Up till now, few theoretical studies were reported. In the only such known attempt, Emmanuel and Plate have established a theoretical model for the two-fold spinning yarn (Emmanuel and Plate, 1982), yet the model was unsolvable due to the fact that the number of independent equations is less than that of the dependent variables.

2. The new model

In this paper we will establish a quasistatic model for the two-strand yarn spinning process. Fig. 1 is an illustration of such two-strand yarn spinning process which in general is of an asymmetric arrangement as shown. We assume the system is in a stable condition.

Taking the special hence simpler symmetrical case, i.e., $\alpha_1 = \alpha_2$, $r_1 = r_2$, $F_1 = F_2 = f$, $M_1 = M_2 = m$, Emmanuel and Plate (1982) obtained the following equations:

$$2f\cos\alpha = F, \tag{1}$$

$$2m\cos\alpha + R\sin\alpha = M. \tag{2}$$

Nonetheless, they were unable to solve these equations, likely because they needed one additional equation to match the number of the dependent variables (f, m, and α).

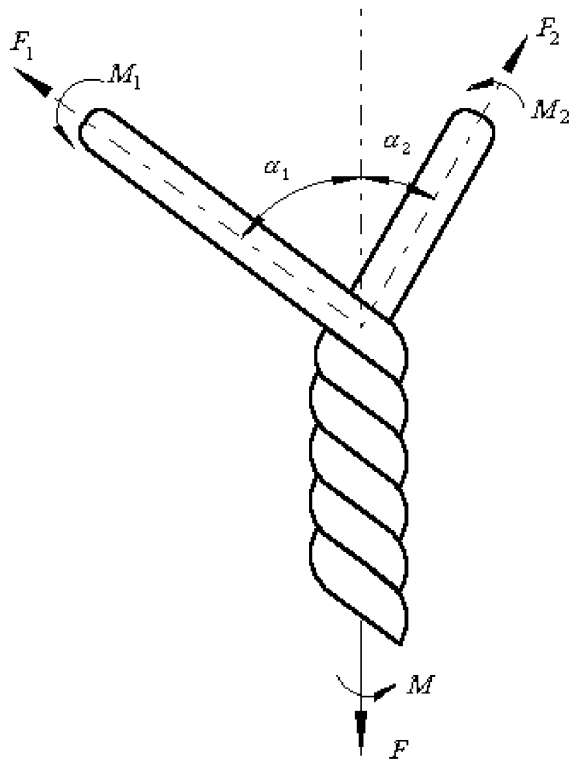

Fig. 1. An asymmetric two-strand yarn spinning.

In order to make the system closed, Miao adopted an experimental procedure to investigate the steady-state two-strand spinning geometry.

We on the other hand consider the system is self-contained, so as to be to provides adequate number of equations.

The system in Fig. 1 must obey basic laws in mechanics, including force balance, mass conservation and energy conservation. The governing equations for the system can, therefore, be written in terms:

(1) Force balances

$$F_1 \cos\alpha_1 + F_2 \cos\alpha_2 = F, \tag{3}$$

$$F_1 \sin\alpha_1 = F_2 \sin\alpha_2, \tag{4}$$

$$M_1 \cos\alpha_1 + M_2 \cos\alpha_2 + R_1F_1 \sin\alpha_1 + R_2F_2 \sin\alpha_2 = M, \tag{5}$$

where F and M are, respectively, tension and elastic torque in the two-strand yarn below the convergence point, F_i and M_i $(i = 1, 2)$ are tension and elastic torque in the two strands above the convergence point. R_1 and R_2 are the radii of the two strands.

(2) Momentum equation

$$\rho_1 u_1 \cos\alpha_1 + \rho_2 u_2 \cos\alpha_2 = \rho u, \tag{6}$$

$$\rho_1 u_1 \sin\alpha_1 = \rho_2 u_2 \sin\alpha_2, \tag{7}$$

where ρ_1 and ρ_2 are the densities of the above two strands, ρ is the density of the spun yarn; u_1 and u_2 are the velocities of the two strands, u is the velocity of the spun yarn.

(3) Mass conservation

$$\pi R_1^2 \rho_1 u_1 + \pi R_2^2 \rho_2 u_2 = \pi R^2 \rho u. \tag{8}$$

(4) Energy conservation

$$\tfrac{1}{2}\rho_1 u_1^2 + \tfrac{1}{2}\rho_2 u_2^2 + \tfrac{1}{2}I_1\omega_1^2 + \tfrac{1}{2}I_2\omega_2^2 = \tfrac{1}{2}\rho u^2 + \tfrac{1}{2}I\omega^2, \tag{9}$$

where I_1, I_2 and I are the inertia coefficients, ω_1, ω_2 and ω are the constant angular velocities.

From the six equations (3)–(9), F_1, F_2, α_1, α_2, M_1, M_2 can be solved. Note that the inlet velocities (u_1 and u_2) of the two strands and the outlet velocity (u) are not independent, they must satisfy the quasistatic condition of the system.

3. Conclusion

We have proposed a self-contained theoretical model dealing with for the first time a seemingly complex dynamic industrial process of critical importance for the industry, especially the specialists in design, manufacturing and using the machine. This model is able to describe a complex dynamic process completely from the theory, and it requires no further empirical or semi-empirical input. Of course the authors understand that no matter how rigorous, some experimentally verification is needed to validate the model. A thorough such experimental work is under way and the results will be reported in a separate paper.

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References

Cheng, K.P.S., Sun, M.N., 1998. Effect of strand spacing and twist multiplier on cotton Sirospun yarn. Textile Res. J. 68, 520–527.

Dhawan, K., Prakash, I., 1987. Effect of roving spacing and twist on quality of cotton double roving feed ring-spun yarns. In: Proc. Papers of 28th Technological Conference. BTRA, SITRA, NITRA and ATIRA, February 1987, pp. 8.1–8.9.

Emmanuel, A., Plate, D.E.A., 1982. An alternative approach to two-fold weaving yarn Part II: The theoretical model. J. Textile Institute (JTI) 73, 107.

Hawary, I.A., 1984. A comparison study between the properties of Sirospun and Normal ring spun cotton yarns, bull. Fac. Eng. Alex Univ. Egypt XXIII, 13–27.

Miao, M., Cai, Z., Zhang, Y., 1993. Influence of machine variables on two-strand yarn spinning geometry. Textile Res. J. 63 (2), 116–120.

Sun, M.N., Cheng, K.P.S., 2000. Structure and properties of cotton Sirospun yarn. Textile Res. J. 70 (3), 261–268.