Research Assessment Exercise 2020
Impact Case Study

University: The Hong Kong Polytechnic University (PolyU)
Unit of Assessment (UoA): 14 - Mechanical engineering, production engineering (incl. manufacturing & industrial engineering), textile technology and aerospace engineering

Title of case study: Green technology improves productivity and creates profit for global textile manufacturers

(1) Summary of the impact

Prof. Xiaoming Tao and her team's fundamental and applied research has created a new market-leading yarn spinning technology – Nu-Torque – providing higher quality products, reducing costs and environmental impact, and significantly increasing productivity. This technology has solved a long-standing industry problem which prevented high-quality high-strength yarn production. Nu-Torque has been licensed by 10 manufacturers including some of the world's largest cotton manufacturers, such as *Luthai Textiles* and *Texhong*. Using Nu-Torque, they have created products for designer brands and high-street retailers such as *Armani* and *UNIQLO*. Nu-Torque products have enabled one company alone to generate over HK$236 million in new profit between October 2013 and September 2019.

(2) Underpinning research

Since the invention of the ring spinning machine in 1828, no-one has solved the problem of single yarns having low strength due to low twist. Higher strength is only possible with higher twist, leading to a problem of 'residual torque' – causing garment seams to twist and curl up. That a single yarn could possess low torque, low twist and high strength simultaneously was widely believed impossible. No ring spinning methods could significantly reduce yarn residual torque by reducing twist. Consequently, an additional process ('setting') was needed, consuming energy, damaging fibers and generating waste gas, waste water and chemical discharges.

To overcome these challenges, Prof. Xiaoming Tao (PolyU Chair Professor of Textile Technology, 2002 to present) and her team developed a new yarn theory that theorizes the adjustment of fiber configuration and stress distribution [1]. They hypothesized and tested the possibility of creating a single yarn structure with low torque, low twist and high strength, and verified their hypothesis experimentally. A single-step method was invented, and the patent was granted in 2005 [2].

Four sponsoring companies funded early-stage research (from late 2002 until 2005) to develop spinning devices and processes with low installation and operation costs suitable for industrial and automatic production. Prof. Tao and her team invented and developed a series of spinning devices with the range of applicable fibers broadened to cover coarse, medium and fine counts in addition to cotton and wool fibers. When developing the methods and devices, the team tackled many technological challenges, including synchronising the device and spinning machine as well as ensuring false-twisting efficiency, spinning device reliability, auto-doffing and fine yarn quality [3, 4]. Due to the research, industrial production of low torque yarn was achieved for the first time in 2006, and the single-step patented method has been continually honed to the present day. Different versions have been patented, with 12 granted patents (the latest in 2013 [5]) and one patent pending (applied for 2018). In 2017-2019, a research collaboration with Chinese company *High Fashion*

applied Nu-Torque technology to spun silk yarn manufacturing for the first time, responding to the demand to reduce industrial pollution from the silk manufacturing process.

On top of developing low torque yarn spinning devices, the team extended their research by establishing an industrial quality assurance/evaluation system through inventing a novel method to accurately control the yarn residual torque on ring spinning machines. The team next created a continuous yarn measurement system for structural analysis [6] and a yarn wet snarling testing method and apparatus, solving the problem of temporary settings and significantly increasing testing accuracy and reliability. Thanks to these inventions, yarn residual torque was, for the first time ever, quantitatively controlled on spinning machine.

The research has been recognized with a total of 11 awards and prizes, including the *First-class Scientific Award by China National Textile and Apparel Council* in 2009 [F], and *the Invention and Venture Award by National Invention Society* (2016). More broadly, in the field of textiles technology research, the research has created a new opportunity to modify spun yarn structures using an active false twisting principle, which may not be limited to ring spinning. This research has also provided new insights into yarn structural mechanics and spinning dynamics

(3) References to the research

[1] Yang K., **Tao X.M.**, Xu B.G. and Lam J., *2007*. Structure and properties of low twist short-staple singles ring spun yarns, Text. Res. J. 77(9):675-685.
[2] **Tao X.M**. and Xu B.G., *2005*. Manufacturing Method and Apparatus for Torque-free Singles Ring Spun Yarns, US Patent No. US 6,860,095 B2.
[3] Xu B.G. and **Tao X.M**., *2008*. Techniques for Torque Modification of Singles Ring Spun Yarns, Text. Res. J., 78(10), 869-879.
[4] Yin R., **Tao X.M**., Xu B.G., *2016*. Mathematical modeling of yarn dynamics in a generalized twisting system, Scientific Reports, 6, Article Number: 24432.
[5] **Tao X.M**., Xu B.G., Hua T., Feng J., Guo H. and Jia Y.H., *2013*. Method and Apparatus for Imparting False Twist to Yarn before Ring Spinning, US Patent No. US 8549830 B1.
[6] Guo, Y., **Tao X.M**., Xu, B.G., Choi, K.F., Hua, T., Wang S.Y., *2010*. A continuous measurement system for yarn structures by an optical method, Measurement Science and Technology, 21(11), Art No. 115706.

The research has been funded by around HK$10 million from government and industry sources since 2002.

(4) Details of the impact

Nu-Torque technology's impact has been felt across the textile industry. The new low torque single yarn technology enables mass production of low torque singles yarns in one step on a single machine with increased spinning productivity, low cost and reduced energy consumption, while producing products with distinct quality improvements [A]. Nu-Torque's commercialization has substantial economic and environmental benefits for the textiles manufacturing industry.

Since 2013 the technology has been further improved, and PolyU now ***directly licenses the technology to over 10 spinning companies*** including *Luthai Textile Co. Ltd, Texhong Textile Group Ltd, Central Textile Ltd, Thai Alliance Textile Co. Ltd*, *Far East Textiles Ltd* and *Chip Tak Textile Co. Ltd*. These licensees have benefited from an ongoing relationship with Prof. Tao who trouble-shoots problems and implements the technology for optimal performance.

Nu-Torque licensees are some of the ***biggest global textile manufacturing companies***. For example, *Luthai*, a world leading cotton textile company, has more than 40 production plants in 8 countries producing 210 million meters of yarn-dyed fabrics, 85 million meters of piece-dyed fabrics and 30 million shirts annually. *Luthai* enjoys strategic partnerships *with Burberry, Calvin Klein, HUGO BOSS, Armani, Gucci, OLYMP,* and *UNIQLO* [B] and has produced ***over RMB 1.1 billion (~HK$1.23 billion) worth of fabric from Nu-Torque yarn in the RAE period*** [C]. Another licensee, *Texhong Textile Group,* is one of the largest cotton textile manufacturers in China with a total workforce of 38,000 employees producing 720,000 tonnes of yarn a year.

Increased profit

Fabrics and apparel made of Nu-Torque yarns by famous brands are widely sold in US, Europe, Japan and China [D]. *Luthai* made ***over RMB 212 million (~HK$ 236 million) in new profit from Nu-Torque*** yarn between 1 January 2014 and 30 September 2019 [C]. *Texhong* produce 2000 tons of Nu-Torque per year averaging ***annual sales of over RMB 50 million (~HK$55.7 million)*** [F].

Improved productivity and environmental benefits

Nu-Torque technology can be easily fitted to existing machines, with immediate benefits for the manufacturer. Nu-torque users confirm ***increased overall productivity of 20-40%*** due to the lower twist level required for the same strength level [F].

These productivity increases also generate ***substantial reductions in energy consumption*** for spinning. *Luthai* noted savings of 1,100 kilowatt hours (kWh) per ton of pure cotton yarn [E]. Producing around 10,000 tons of Nu-Torque yarn between 1 October 2013 and 30 September 2019 [C], this is estimated ***savings of 11 million kWh*** (note the typical American home uses 7,200 kWh per year). As well substantially reducing environmental impact, this is an estimated economic ***saving of around HK$ 9.1 million*** [G].

This technology ***streamlines the production process***, eliminating yarn plying and setting processes, thus further reducing costs, energy consumption, fiber damage as well as waste gas, water and chemical discharges. As Nu-Torque requires no chemical, water or steam during the production process it provides a ***long term environmentally sustainable manufacturing process*** [E].

Industry has also benefitted from the evaluation system developed during the research. *Central Textiles* described how they used this system "*to test the yarn torque, monitor the quality of the yarn and for yarn product development. **It saves time, reduces development costs and is reliable and has become the company's main examination system** of the sweater / knitting yarn products*" [D].

Better quality

Central Textiles note ***improved product quality***: "*[We have] successfully applied the Nu-Torque technology invented by PolyU to develop an extra soft yarn (branded as ESTex – Extra Soft Textile). The features of this newly developed yarn include high strength, less hairiness, high gloss and small yarn residual. The fabric is with soft and smooth surface and deformation after washing is limited*" [D]. *Texhong* confirm that "*due to the high quality, low twist yarns have been well received by customers and have entered into overseas markets"* [F].

Nu-Torque's versatility enables manufacturers to ***improve a wide range of products***. For example, knitted fabrics have low spirality after washing and possess unique 'soft handle'; towels have a 'full handle' (soft, fluffy) and a high level of water absorption; clothes possess smooth and clean surfaces that are cashmere soft. ***Far higher quality products***, ranging from cotton sweaters, t-shirts, jeans, flannel clothing to towels, can be produced using Nu-Torque technology [H].

Nu-Torque's improved quality is shown in this comparison to conventional yarn

(5) Sources to corroborate the impact (indicative maximum of 10 references)

[A] Luthai website - Research on Nu-Torque yarn and its fabric technique (archived July 2019)
[B] Luthai website (archived November 2019)
[C] Letter from Luthai Textile Co. Ltd, October 2019
[D] Letter from Central Textiles, March 2014
[E] Letter from Luthai Textile Co. Ltd, January 2019
[F] Letter from Texhong Textiles, December 2018
[G] Average calculation for period taken from electricity prices for industry in Jinan, China: https://www.ceicdata.com/en/china/electricity-price
[H] HKRITA video about Nu-Torque Cotton Yarn Production Technology. http://www.hkrita.com/en-us/videos/listing/page:3