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The Effect of Humidified Air on Yarn Properties in a Jet-Ring Spinning System

Vpliv navlaženega zraka na lastnosti preje, izdelane v curkovnem prstanskem predilnem sistemu

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Abstract
In this study, the effect of 100% atmospheric relative humidity on yarn properties was investigated using jet-ring nozzles and compared with the yarn properties of yarns produced with air operated jet-ring nozzles under normal conditions. As a humidification system, a pneumatic conditioner, also known as a lubricant, was used in pneumatic systems. This conditioner was connected just before the pneumatic distributor that supplies air to the nozzles. The tube in stage 2 of the conditioner was filled with pure water at room temperature (25 °C ± 2 °C). The air conditioner dose was adjusted to 100% atmospheric relative humidity. The use of humidified air to jet-ring nozzles had a slight positive effect on all yarn properties (yarn hairiness, yarn irregularity, yarn elongation and yarn tenacity). According to the results, it resulted in a 1% to 3% improvement in yarn quality. This study is the first example and an original study in this field, as there is no study using humidified air in existing jet-ring air nozzle studies. It was proven in this study that humidified air results in a slight improvement in yarn properties.
Keywords: yarn quality, yarn hairiness, jet-ring, nozzle-ring, air nozzle, yarn properties

Izvleček
V tej študiji je bil proučevan vpliv 100-odstotne relativne zračne vlažnosti na lastnosti preje, izdelane z uporabo curkovnih šob, in njena primerjava z lastnostmi preje, izdelane z uporabo curkovnih šob v normalnih okoliščinah. Kot sistem za vlaženje se v pnevmatskih sistemih uporablja pnevmatski vlažilec, ki se uporablja tudi kot mastilna naprava. Ta naprava je nameščena tik pred pnevmatski razdelilnik, ki v šobe dovaja zrak. Cevka mastilne naprave je bila v drugi fazi napolnjena s čisto vodo sobne temperature (25 °C ± 2 °C). Delovanje klimatske naprave je bilo naravnano na 100-odstotno relativno vlažnost zraka. Uporaba navlaženega zraka na curkovni šobi je nekoliko izboljšala vse lastnosti preje (kosmatost, neenakomernost, raztezek in trdnost preje). Rezultati zagotavljajo 1–3-odstotno izboljšanje kakovosti preje. Ta študija je prva na tem področju, saj v obstoječih študijah prstanskih curkovnih šob uporaba navlaženega zraka ni znana.
Ključne besede: kakovost preje, kosmatost preje, curek-prstan, obroč šobe, zračna šoba, lastnosti preje

1 Introduction

Within the textile sector, the measurement and evaluation of yarn hairiness and hairiness variation on the yarn gradient line is an important part of the total quality control of a yarn. Particularly as the result of various technological developments, an increase in machine speeds and an increase in quality expectations, yarn hairiness has become an important yarn parameter that should be controlled through measurement.

Spinning systems used in yarn production function according to the principle of real or false twist. The most typical example of a spinning machine functioning according to the actual bending principle is the conventional ring spinning system. The conventional ring spinning system, one of the first developed spinning systems, has been one of the most widely used spinning methods from the past to the present. One end of a fibre bundle or group of filaments is held constant while the twist type based on the principle of turning the other end along its axis is called a true twist. In contrast, a false twist imparts a temporary twist to the fibre bundle. However, after separation from the twist element, the fibres are parallel and untwisted. As a result, there is no twist on the fibre bundle and therefore no real strength is imparted to the yarn. This principle is contrary to normal yarn with the specific requirement to gain strength. Nevertheless, if the system is modified, it is possible to spin a yarn with a suitable strength value with the false twist principle in the same system.

The most important developments in the field of spinning have been in the field of false twist or winding spinning. The original idea of the false twist principle is based on the addition of fibres to the false twist structure following the removal of the torque at the output of the false twist element and the rotation of the inserted fibres in the opposite direction. This is very similar to the idea that the fibres emerging from the yarn surface are wound around the centre of the yarn. Such fibres trapped in the structure ensure the high cohesion of the yarn even after twisting. Various researchers have used devices and processes that have similar effects on their patents. One of the most important patents is Murata's air-jet spinning system.

The first design for the concept of obtaining fibres by collecting and twisting fibres using a rotating fluid was developed by Götzfried [1]. Götzfried [1] and then Pacholski et al. [2] showed that air jets entering tangentially into the nozzle hole caused a vortex in the nozzle, and could be twisted to the yarn passing through the centre of the rotating air stream at high speeds [3]. The development of modified spinning systems with the addition of air nozzles to various spinning systems and research on the effect of these systems on yarn properties have been studied in recent years.

1.1 Jet-ring (nozzle-ring) spinning system

This system is based on the placement of air nozzles used in the air-jet spinning system between the output system of the conventional ring spinning system and the yarn guide system, referred to as a jet-ring or nozzle-ring (Figure 1). Air is fed into the air nozzle used in the jet-ring system at a certain pressure value. Compressed air creates a rotating air vortex in the nozzle. The air vortex ensures that the fibre ends that protrude outward from the yarn body are wound up in the yarn body, thereby reducing yarn hairiness [5]. In addition to low yarn hairiness, fabrics made from the aforementioned yarns are smoother and more resistant to pilling than fabrics made from conventional ring-spun yarns. Air nozzles thus provide improved yarn properties and long-term advantages due to improvements in fabric performance.

Figure 1: Use of an air nozzle on a jet-ring spinning system

The first experiments with jet -ring or nozzle-ring spinning system were carried out towards the end of the 1990s by Wang et al. [6]. Recently, however, many researchers have been working on yarn properties, in particular on the improvement of yarn hairiness over the use of air nozzles in a conventional ring spinning system [5–9]. Yilmaz [7] evaluated the effect of a pseudo-twist on the yarn properties of compressed air fed into the air ring in the conventional ring spinning system. In order to determine the performance of the core, the yarns produced as Ne 30/1 yarn represent the linear density. In this study, the air nozzle in the conventional ring spinning systems were assembled and produced using yarns, referred in literature as "jet-ring yarn". Yilmaz determined that there was not a single type of flat hair with the lowest hairiness values. It has been determined that the rate of improvement in hairiness values changes depending on the structural parameters and air pressure value. However, it was found that different yarn types were effective on other yarn properties that determine the yarn quality, as well as yarn hairiness. It was determined that a jet-ring modified yarn spinning system consisting of an air nozzle results in a reduction in the number of short fibres of measuring 1 mm and 2 mm, as well as the long hair count.

2 Material and methods

2.1 Air nozzle

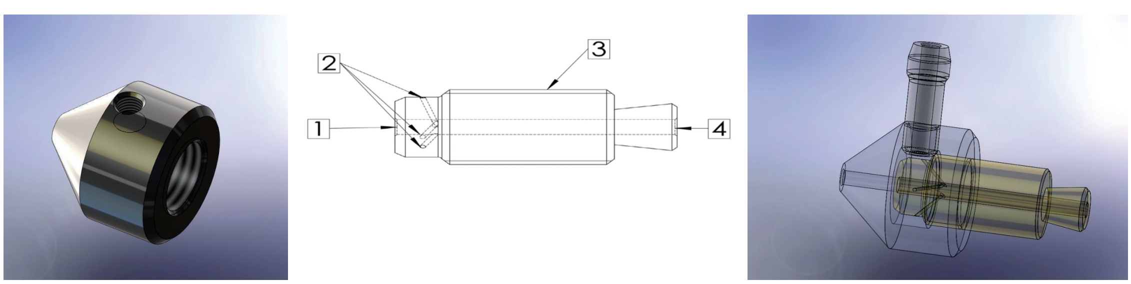
A jet-ring (nozzle-ring) spinning system comprises three basic components: compressed air, nozzle and yarn. Compressed air with a certain value from the compressor is transported to the level and passed through the thread. The nozzle assembly (Figure 2c) has a very simple structure and consists of a nozzle housing (Figure 2a) and nozzle body (Figure 2b). The nozzle body part has a circular cross-section consisting of the twisting chamber (main hole) (1), injectors (2), connecting screw for the nozzle housing (3) and the nozzle outlet (4) (Figure 2b). The main hole extends from the nozzle inlet to the nozzle outlet. The injectors are positioned tangentially to the twisting chamber. The nozzle housing conveys the compressed air from the compressor to the twisting chamber section of the device via the injectors [8, 9]. Flow volume is illustrated in Figure 3. As shown in Figure 3, the design parameters of the air nozzles are composed of twist chamber diameter (*Dtc*), injector diameter (*Di*) and injector angle (θ). A nozzle length is 27mm and twisting chamber diameter of $\phi = 2$ mm was maintained in all samples.

2.2 Experimental setup

The structural parameters of the jet-ring nozzle used to determine the effect on air humidified nozzles are given in Table 1. Ten nozzle types were defined for this experiment. Generally, air nozzles do not work on a bending chamber diameter of more than $\phi = 3$ mm and an injector diameter of more than $\phi = 0.9$ mm [5, 7, 9]. In this study, samples with large twist chamber and injector diameters were preferred in order to minimize the effect of humidified and increased air density on the pressure loss problem. Yarn production was performed using a Merlin SP43 conventional ring spinning machine made by the Pinter Group, with a capacity of 16 spindles. Jet-ring air nozzles mounted on a conventional ring spinning machine are shown in Figure 4.

2.3 Air humidifier system

A pneumatic conditioner, also known as a lubricant, was used as the air humidification system, which is generally connected to the compressor outlet in pneumatic systems (Figure 5). This conditioner was connected just before the pneumatic distributor that supplies air to the nozzles. A typical pneumatic lubricant consists of two stages. In the first stage, the



a) b) c)

Figure 2: Nozzle (a) housing, (b) body and (c) assembly

moisture in the air is maintained, i.e. atmospheric humidity is established. Water is an undesirable feature in pistons, cylinders, pneumatic actuators or similar systems that generally operate within a pneumatic system. For this reason, special pneumatic dryers are also used in large industrial plants. In the second stage of the conditioner, the dried air was lubricated using oil contained in the conditioner tube at the desired dose. The aim of this approach is to ensure that pneumatic systems function with oil, silently and over a long useful life. In this study, it was used outside the purpose of the conditioner. The tube in the second stage of the conditioner was filled with pure water at room temperature (25 °C ± 2 °C) instead of oil. The air leaving the conditioner in this way can be air containing moisture or even water instead of oily air. The aim of this study was not to contain water, but to obtain air with 100% relative humidity. Therefore, before starting the experiment, the conditioner dose was adjusted to 100% relative humidity. Humidity measurements were confirmed using an E+E brand model EE160 temperature and relative humidity transmitter (Figure 6). The EE160 temperature and relative humidity transmitter can

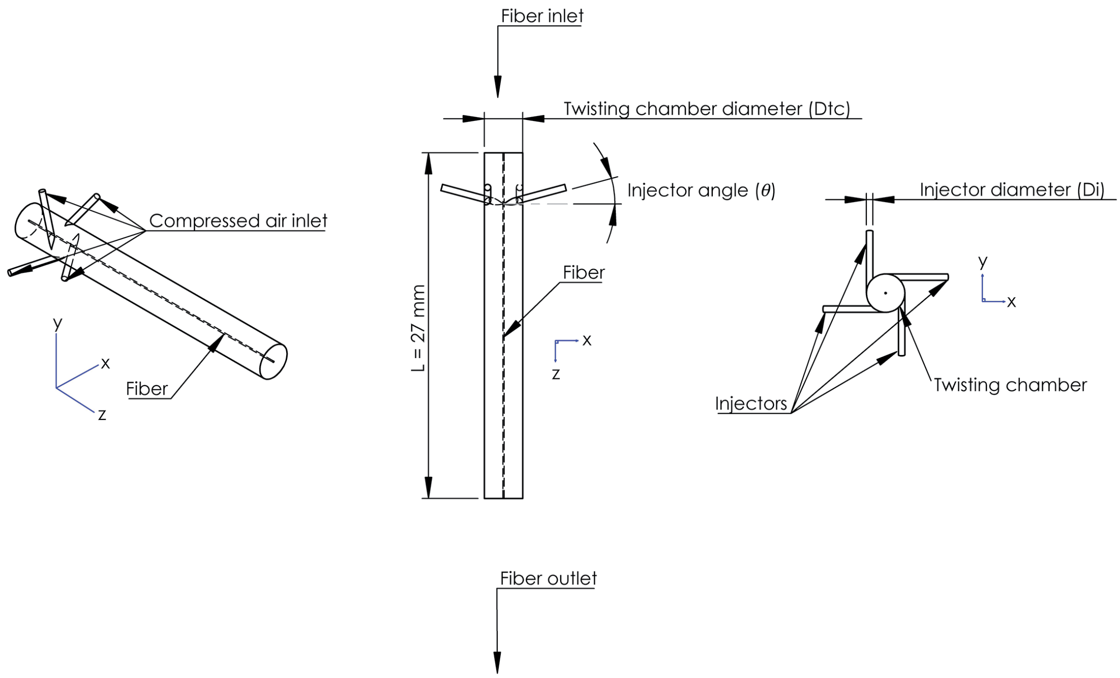


Figure 3: 3D model drawing of a conventional nozzle flow volume with four injectors

Table 1: The structural parameters of the jet-ring nozzle

Nozzle no.	(mm)	Injector diameter (mm)	Injector qty	Injector angle (°)
1	3	0.8	4	20
2	3	0.8	4	25
3	3	0.8	4	30
4	3	0.8	4	35
5	3	0.8	4	40
6	3	0.9	4	20
7	3	0.9	4	25
8	3	0.9	4	30
9	3	0.9	4	35
10	3	0.9	4	40

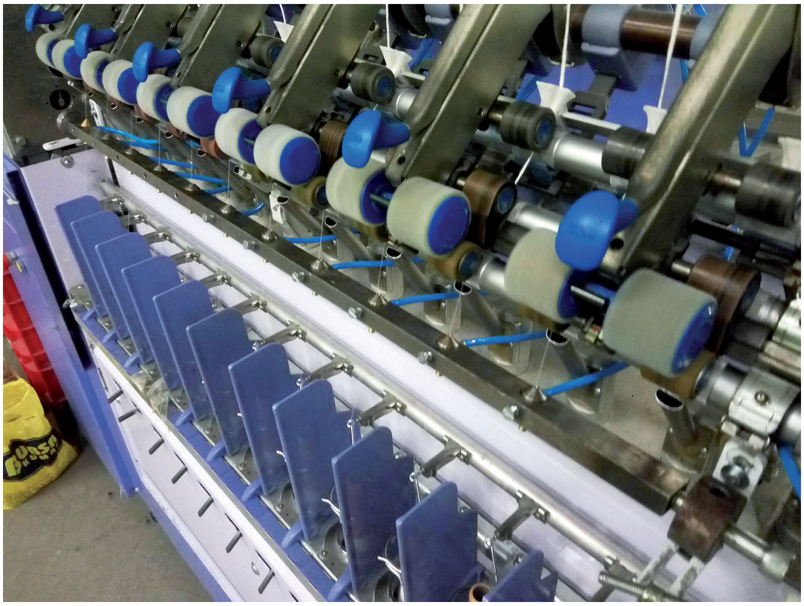


Figure 4: Jet-ring air nozzles mounted on a conventional ring spinning machine

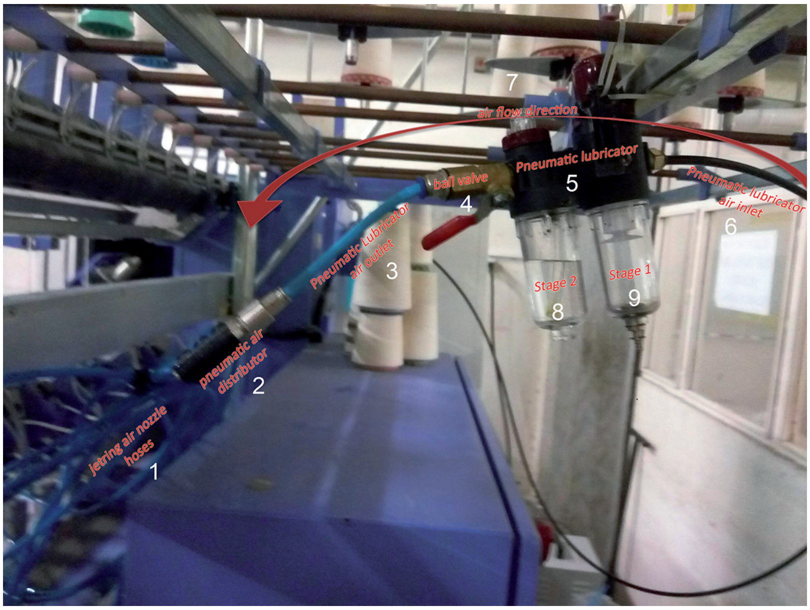


Figure 5: Pneumatic lubricator for use with an air-nozzle humidifier
1 – jetring air nozzle hoses, 2 – pneumatic air distributor, 3 – pneumatic lubricator - air outlet, 4 – ball valve, 5 – pneumatic lubricator, 6 – pneumatic lubricator – air inlet, 7 – air flow direction, 8 – stage 2, 9 – stage 1

be used to measure ambient temperature with an accuracy of ± 0.3 °C and relative humidity with an accuracy of ± 2.5%. With its analog/modbus output, the EE160 can transfer digital data to PLC (programmable logic controller) or HMI (human machine interface, touch screen) systems. In this study, EE160 temperature and humidity transmitter was connected to an electrical panel containing an HMI, and data analysis was performed (Figure 7).

2.4 Yarn production

One-hundred percent cotton yarns were produced in this experiment. We produced cotton jet-ring yarns of 19.6 tex (Table 2). In all yarn productions, importance was given to working with the same spinning parameters, e.g., the same twist multiplier, draft, spindle speed and traveller type (Table 3). The number of injectors was kept constant as four pieces. In all jet-ring yarn productions, the air pressure was kept at 125 kPa (gauge).

Figure 6: E+E EE160 temperature and humidity transmitter

Figure 7: Electrical panel containing HMI

Table 2: Fibre properties

Fibre properties	19.6 tex
Staple length (mm)	30.53
Micronaire	4.52
U.I. (uniformity index)	85.7
Strength (cN/tex)	34.5
Breaking elongation (%)	6.4
SFI (short fibre index)	6.9
+b (yellowness)	7.9
Rd (reflectance degree)	72.1
CG (colour grade)	41–2
SCI (spinning count index)	160

Table 3: Spinning particulars

Parameters	19.6 tex
Roving count (tex)	472
Twist (1/m)	830
α_e	3.7
Mean spindle speed (rpm)	13000
Take up speed (m/min)	15.7
Traveller type	SFB 2.8 PM udr
Traveller ISO No.	31.5–50
Ring diameter (mm)	38
Draft/Break draft	1.181
Total draft	50.4

2.5 Yarn tests

Yarn hairiness, irregularity and imperfection tests were carried out using an Uster Tester 3. Tensile property (percentage of elongation and tenacity measured as cN/tex) tests were carried out using an Uster Tensorapid. The cops and bobbins of each system were fed in the same order to the testers. Yarn test details are given in Table 4. The tests were

Table 4: Test particulars for each yarn sample

Yarn properties	Test device	Test length (m)	Test number	Total length (m)
Yarn irregularity and imperfections	Uster Tester 3	400	1	400
Yarn hairiness	Uster Tester 3	400	1	400
Tensile properties	Uster Tensorapid	0.5	10	5

carried out under the same atmospheric conditions (75% ± 5% relative humidity and 25 °C ± 2 °C), and we conditioned samples for a minimum of 72 hours before the tests. All the tests were carried out on the same testers and test results were analysed statistically to determine any significant differences.

3 Results and discussion

3.1 Yarn hairiness results

The effect of conditioned and normal air on yarn hairiness (H) is illustrated in Figure 8 for an injector diameter of $\phi = 0.8$ mm and in Figure 9 for an injector diameter of $\phi = 0.9$ mm. In both injector diameter values, normal air and conditioned air resulted in similar hairiness values in the first measurement. In the second measurement one week later, an increase in hairiness was expected, as the yarn was completely dry. On the contrary, however, a surprising slight reduction in hairiness occurred. For yarn produced using a humidified air nozzle, hairiness values in the second measurement (after one week) decreased by approximately 0.1–0.2 compared to the hairiness values in other measurements. Conditioning (humidified) air improves the yarn hairiness value. Expressed in percentages, it means an improvement in hairiness of about 1.5% to 3.5%.

3.2 Yarn irregularity results

The effect of conditioned and normal air on yarn irregularity (% Cv m) is illustrated in Figure 10 for an injector diameter of $\phi = 0.8$ mm and in Figure 11 for an injector diameter of $\phi = 0.9$ mm. A slight decrease in yarn unevenness was observed according to the condensed air measurements of an injector diameter of $\phi = 0.9$ mm. The situation is slightly different for condensed air measurements of yarns produced in configurations with an injector diameter of $\phi = 0.8$ mm. A reduction in yarn irregularity was observed when using humidified air in 20° and 25° nozzle configurations. However, the yarn irregularity value increased in both in a 30° nozzle configuration, and in a 35° nozzle configuration (second condition) and in a 40° nozzle configuration (first condition). Nevertheless, in general, it can be said that the yarn irregularity value is reduced by 0.1% to 0.4% in yarns produced with humidified air. Humidified air was observed to improve both yarn irregularity and yarn hairiness.

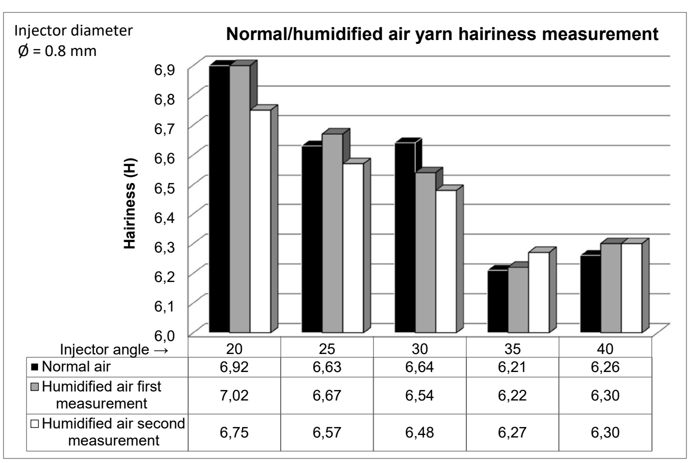
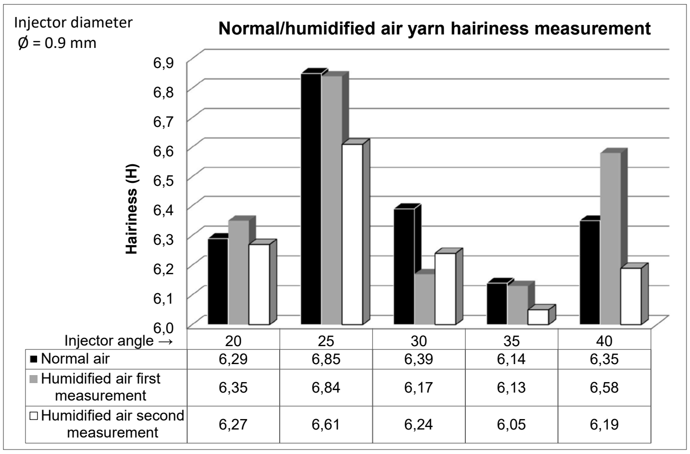
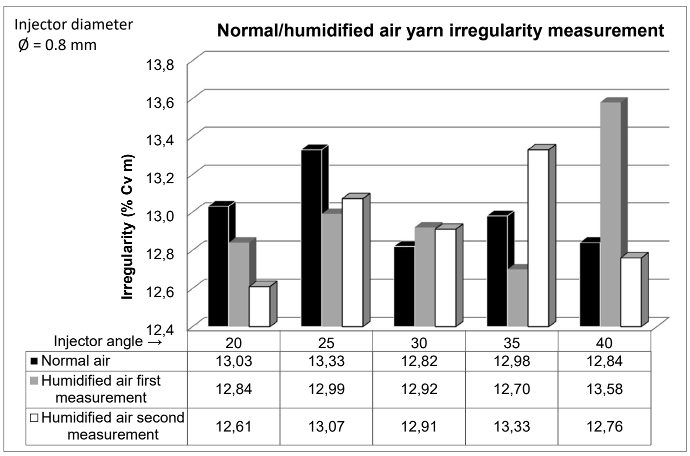


Figure 8: Effect of conditioned and normal air on yarn hairiness (injector diameter: $\phi = 0.8$ mm)



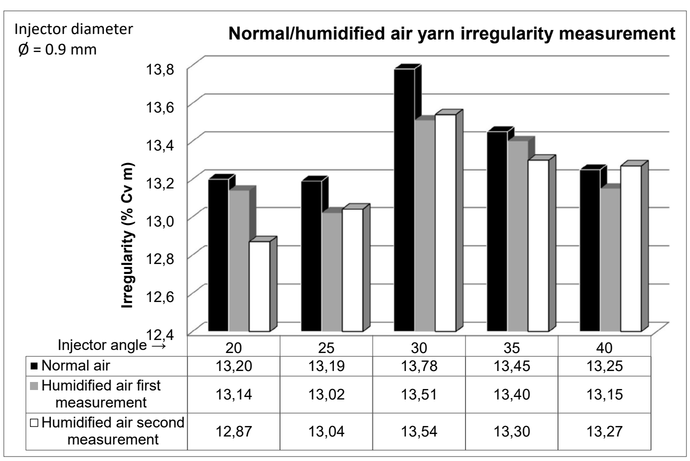
Injector angle →	20	25	30	35	40
■ Normal air	6,29	6,85	6,39	6,14	6,35
■ Humidified air first measurement	6,35	6,84	6,17	6,13	6,58
□ Humidified air second measurement	6,27	6,61	6,24	6,05	6,19

Figure 9: Effect of conditioned and normal air on yarn hairiness (injector diameter: $\phi = 0.9$ mm)



Injector angle →	20	25	30	35	40
■ Normal air	13,03	13,33	12,82	12,98	12,84
■ Humidified air first measurement	12,84	12,99	12,92	12,70	13,58
□ Humidified air second measurement	12,61	13,07	12,91	13,33	12,76

Figure 10: Effect of conditioned and normal air on yarn irregularity (injector diameter: $\phi = 0.8$ mm)



Injector angle →	20	25	30	35	40
■ Normal air	13,20	13,19	13,78	13,45	13,25
■ Humidified air first measurement	13,14	13,02	13,51	13,40	13,15
□ Humidified air second measurement	12,87	13,04	13,54	13,30	13,27

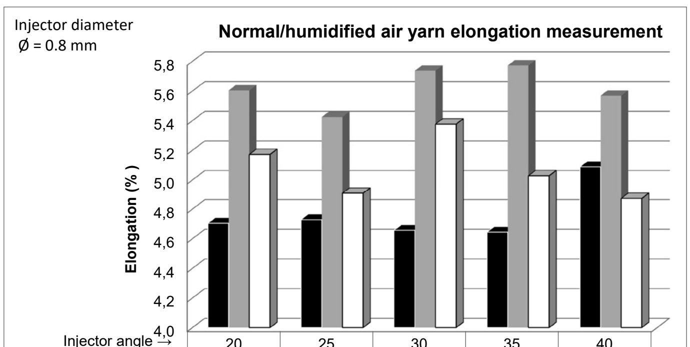
Figure 11: Effect of conditioned and normal air on yarn irregularity (injector diameter: $\phi = 0.9$ mm)

3.3 Yarn elongation results

The effect of conditioned and normal air on yarn elongation (%) is illustrated in Figure 12 for an injector diameter of ϕ = 0.8 mm and in Figure 13 for an injector diameter of ϕ = 0.9 mm. If the second measurement of the humidified nozzle of ϕ = 0.8 mm injector diameter and 40° nozzle is not taken into account, the elongation at break in all samples produced with conditioned air is in the range of 0.5–1% in the first measurement and 0.2–0.8% in the second measurement, where an increase was observed. The reduction in yarn elongation between the first measurement and the second measurement was 0.2% to 0.3%. The humidified air was also observed to improve the yarn elongation property of the yarn, as in the previous results.

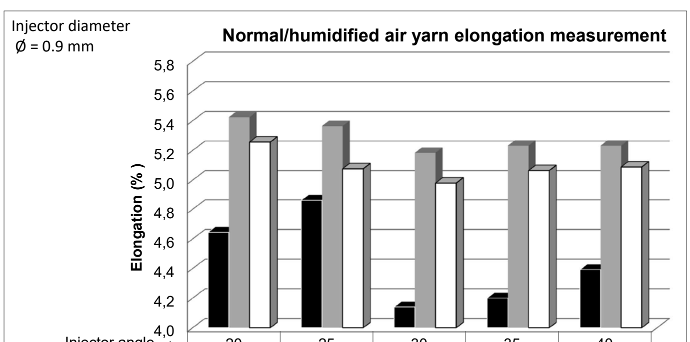
3.4 Yarn tenacity results

The effect of conditioned and normal air on yarn tenacity (cN/tex) is illustrated in Figure 14 for an injector diameter of ϕ = 0.8 mm and in Figure 15 for an injector diameter of ϕ = 0.9 mm. In the nozzle configurations with an injector diameter of ϕ = 0.8 mm, the strength values increased in the first measurement of the humidified air nozzle. In the second measurement of the humidified air sample, however, the strength values were similar to those of normal air. In all other nozzle configurations, except 25° with an injector diameter of ϕ = 0.9 mm, both of the humidified air sample measurements show an average yarn tenacity increase of 0.9–1.8 cN/tex in all samples. Thus, in all other nozzle configurations except 25°, the use of conditioned air results in an increase in yarn tenacity of about 11% to 16%.



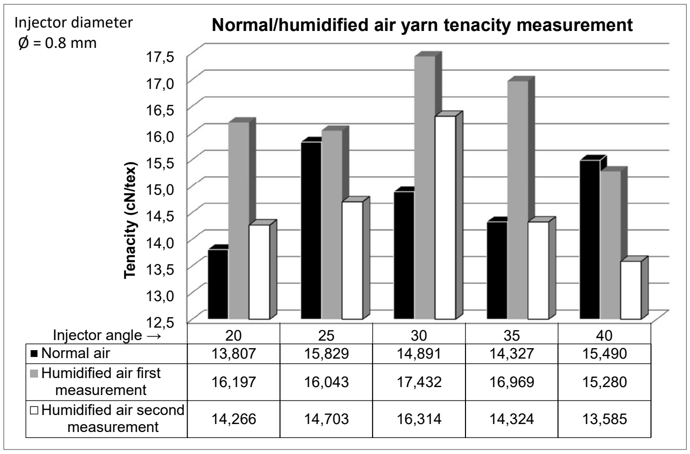
Injector angle →	20	25	30	35	40
■ Normal air	4,704	4,728	4,656	4,644	5,088
■ Humidified air first measurement	5,604	5,424	5,736	5,772	5,568
□ Humidified air second measurement	5,172	4,908	5,376	5,028	4,872

Figure 12: Effect of conditioned and normal air on yarn elongation (injector diameter: ϕ = 0.8 mm)



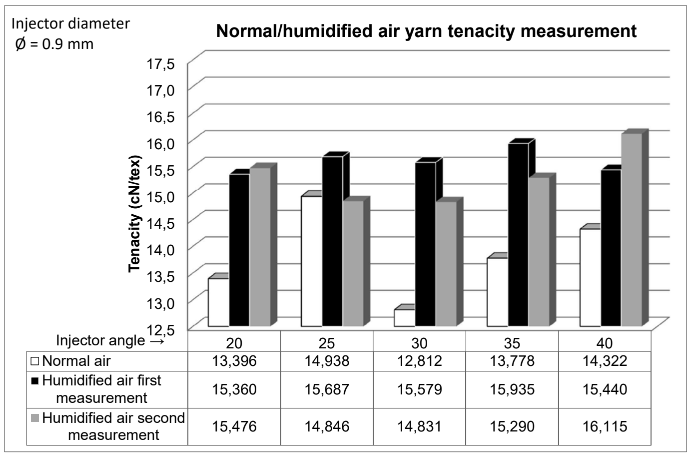
Injector angle →	20	25	30	35	40
■ Normal air	4,644	4,860	4,140	4,200	4,392
■ Humidified air first measurement	5,424	5,364	5,184	5,232	5,232
□ Humidified air second measurement	5,256	5,076	4,980	5,064	5,088

Figure 13: Effect of conditioned and normal air on yarn elongation (injector diameter: ϕ = 0.9 mm)



Injector angle →	20	25	30	35	40
■ Normal air	13,807	15,829	14,891	14,327	15,490
■ Humidified air first measurement	16,197	16,043	17,432	16,969	15,280
□ Humidified air second measurement	14,266	14,703	16,314	14,324	13,585

Figure 14: Effect of conditioned and normal air on yarn tenacity (injector diameter: $\phi = 0.8$ mm)



Injector angle →	20	25	30	35	40
□ Normal air	13,396	14,938	12,812	13,778	14,322
■ Humidified air first measurement	15,360	15,687	15,579	15,935	15,440
■ Humidified air second measurement	15,476	14,846	14,831	15,290	16,115

Figure 15: Effect of conditioned and normal air on yarn tenacity (injector diameter: $\phi = 0.9$ mm)

4 Conclusion

- The use of humidified air on jet-rings had a slight positive effect on all yarn properties (yarn hairiness, yarn irregularity, yarn elongation and yarn tenacity). According to the results, a 1% -3% improvement in yarn quality was achieved.
- In moistened nozzle applications, the second measurement was expected to be regressed or slightly reduced compared to the first measurement. On the contrary, however, an improvement was seen in yarn hairiness and yarn irregularity between the first and second measurements. Yarn elongation and yarn tenacity values decreased slightly as expected.
- In this study, humidification experiments were not performed on different nozzle types. We recommend that researchers work with different types of nozzles in future studies, as there is a higher likelihood of improvement in other types of nozzles.
- During the experiment with the humidified air, there were no yarn breaks due to friction, irregularity or other reasons. Humidified air was also observed to reduce yarn breaks.

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