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Design and Develop the Single Jet Nozzles and Fabrication of Single Head Single Jet Spinning Unit

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Abstract

An attempt has been made through this research work by developing single air jet nozzle and fabricating a single head jet spinning unit for producing air jet yarns with minimum fiber loss and improved yarn characteristics. In the part 1, explain about research work done on newly designed and developed of single jet nozzle and Single head single jet spinning was fabricated. Designed single jet nozzle was carried out in three phases. In the first phase, 11 Nozzles were developed with different dimensions. In the second phase five nozzles were developed with Inner flanged type wrapper fibre chambers in various air fed angle such as 45^o, 50 ^{o}, 55 ^{o}, 60 ^{o} and 65 ^{o}. In third phase five nozzles were developed with Rectangular shape type wrapper fibre chambers in various air fed angle such as 45^o, 50 ^{o}, 55 ^{o}, 60 ^{o} and 65 ^{o}. The single jet nozzle consists of Air inlet chamber, Wrapper fibre chamber, false twist chamber and Fasciated yarn chamber. Single head single jet spinning was fabricated and necessary modifications were carried out to achieve high draft range of 10-250 and delivery speed of 150 m/min by servo motor for the drafting zone, winding zone and above nozzle fixed in drafting system.

Key words: Design, single jet nozzles, Air inlet chamber, Inner flanged type & Rectangular shape type Wrapper fibre chamber, False twist chamber and Fasciated yarn chamber.

1 Introduction

Ring spinning has undergone steady development and achieved significant superiority in the past 100 years. For the past 50 years, many attempts have been made to surpass limitations of ring spinning (1). These attempts to surpass limitations have led to the development of new and innovative principle methods such as adhesives, open end spinning and false twist spinning techniques (2 to 11). As a way of fascinated yarn production, there were many attempts for the air-jet spinning innovations such as "Dupont" in 1956, "Rotofil" in 1971, "Toyada" in 1983, "Toray" in 1985, etc. But these methods had little commercial success. Two nozzle Air jet spinning has become established in synthetic double yarns, particularly in polyester staple fibers. Using both false twist and open end spinning technology, air vortex spinning system was initially introduced for natural fibers and recently it is used for viscose fibers due to reduction in fibre loss and competitive yarn quality. So, the limitations in fasciated spinning process were continued. An attempt has been made through this research work by developing single air jet nozzle and fabricating a single head jet spinning unit for producing air jet yarns with minimum fibre loss and improved yarn characteristics. In this part 1, the different materials and methods used in design and development of single jet nozzle, fabrication of single head single jet spinning unit were dealt.

2 Material and Methods

The design and development of the single jet nozzle with various design parameters was carried out based on the principles of nozzle used by DU-PONT, Murata air jet spinning, Murata air vortex spinning and with other references from various journals. For design and development of nozzle, contour drawings were made using AUTOCAD 2006 and a wooden cut section model has been made for preliminary investigation. The nozzle No. 1 to 11 (shown in Table 1) has been fabricated using the above aluminum alloy and trials were conducted. Aluminum alloy of grade 6061 has been selected to fabricate the nozzle. After completing the first phase trials, it is concluded that nozzle 12 to 21 (shown in Table 2) are suitable for subsequent research. For these nozzles Poly Tetra Fluoro Ethylene (PTFE) is coated for a thickness of thirty microns to get improved nozzle characteristics such as low friction, high chemical resistance, high wear assistance and nonstick surface. Highly automated CNC lathe make Shalimar Machine Tools (Model SJ-25/35) and Tool multiple angle grinding machine HMT make (Model CTR-1) were used for fabrication of the nozzle to get high accuracy and tolerance limit.

The design and development of single jet nozzle was carried out in three phases for this research work. In the first phase, 11 Nozzles were developed with different dimensions as shown in Table 1. In the first 9 nozzles, various dimension and construction changes were done. All the 9 nozzles were found inappropriate for yarn formation. A construction change for improvement in each nozzle was done based on running performance of the earlier nozzle. Some of the important design changes like Air inlet fed angle, hollow spindle diameter variations, no of drillings made, offset of the air fed angles, drilling diameter reduction and varying the distance between the front roller nip to the air nozzle zone.

In the second & third phase, 10 Nozzles were developed with different dimensions as shown in Table 2. In the first 9 nozzles, various dimension and construction changes were done In the second phase 5 nozzles were developed with wrapper fibre chambers of Inner flanged type in at various air fed angles such as 45^{o}, 50 ^{o}, 55 ^{o}, 60 ^{o} and 65 ^{o}. In the third phase five different nozzles were developed with wrapper fibre chambers of rectangular type in at various air fed angles such as 45^{o}, 50 ^{o}, 55 ^{o}, 60 ^{o} and 65 ^{o}.Using experiment and slip-up principle, trials were conducted using 21 different nozzles. Based on trial runs, the working performances of all the nozzles were critically analyzed.

Table 1 Nozzle Details and working performance in phase I

Nozzle Number	Nozzle Dimensions			Air fed angle in Degrees	Number of slots	Slot orifice dia in mm	Slots in the Nozzle - Either offset or Not	Hollow Spindle dimensions Top dia x bottom dia in mm	Incorporation of Wrapper fibre chamber	Working Performance
	Length in mm	Width in mm	Height in mm							
Phase I										
1	45	60	90	85	4	1	No	5.0 X 5.0	No	No Yarn
2	45	60	80	85	4	1	No	4.5 X 4.5	No	
3	45	60	70	80	4	1	No	4.2 X 4.2	No	
4	45	60	60	75	4	1	No	4.0 X 4.0	No	
5	45	60	50	70	4	1	Yes	3.5 X 3.5	No	
6	30	20	35	65	3	1	Yes	3.0 X 3.0	No	
7	30	20	35	65	3	0.75	Yes	2.8 X 2.8	No	
8	30	20	35	65	3	0.75	Yes	2.8 X 2.6	No	
9	30	20	35	45	3	0.75	Yes	2.5 X 2.5	No	
10	30	20	35	45	3	0.75	Yes	2.2 X 2.0	No	
11	25	20	23	45	3	0.75	Yes	2.2 X 1.5	Yes	Yarn formed

Table 2 Nozzle Details and working performance in phase II and phase III

Nozzle Number	Nozzle Dimensions			Air fed angle in degree	Number of slots	Slot orifice dia in mm	Spindle dimensions Top dia x bottom	Type of Wrapper fiber chamber	Working Performance
	Length in mm	Width in mm	Height in mm						
Phase II									
12	25	20	23	45	3	0.75	2.2 X 1.5	Inner Flanged Wrapper Fibre Chamber	Yarn is formed with satisfactory strength.
13				50					

14				55					
15				60					
16				65					
Phase III									
17	25	20	23	45	3	0.75	2.2 X 1.5	Rectangular Wrapper Fibre Chamber	Yarn is formed satisfactory strength.
18				50					
19				55					
20				60					
21				65					

3 Results and Discussion

The nozzle consist of an air inlet chamber, wrapper fibre chamber, false twist chamber and fasciated yarn chamber which are shown in Figure 1.Using AUTOCAD the cut cross section of various components of the assembled nozzle were developed.

The air fed angle which creates slots in the nozzle are developed with different air fed angles such as 45o, 50o, 55o, 60 o and 65o.This angle is made between the center of the nozzle and the tangential line to the slot (as shown in Figure-1).From the working performance analysis of different nozzles, it was observed that nozzle 1to 11 are not suitable and the remaining nozzles 12 to 21 were taken for further research work. The detailed description of the individual components of the developed nozzle such as air inlet chamber, wrapper fibre chamber, false twist chamber and fasciated yarn chamber are given below. Figure 2 shows the Assembled nozzle and components of nozzle. The Figure 3 shows the assembled line diagram of developed Jet nozzle. Using Auto CAD 2006 software the cut cross sectional view of the single jet nozzle No.12 is shown in Figure 4

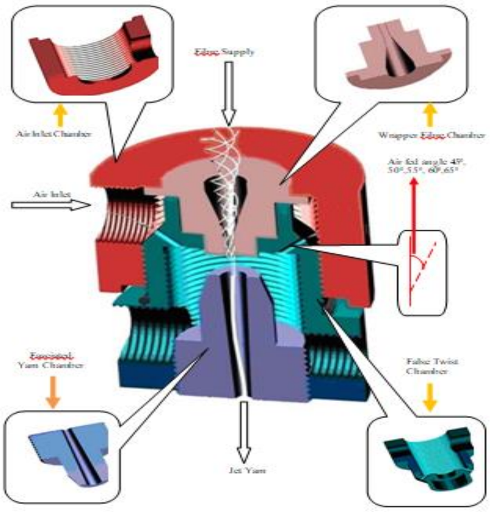


Figure 1 - 3D Assembled Cut Cross Section of the Developed Nozzle and the Cut Cross Section of the Individual Components

Figure 2 -Assembled nozzle and components of nozzle

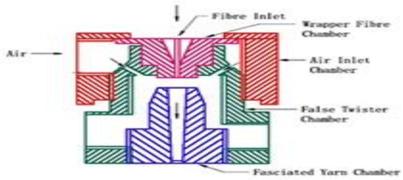


Figure 3- Line diagram of the developed jet nozzle

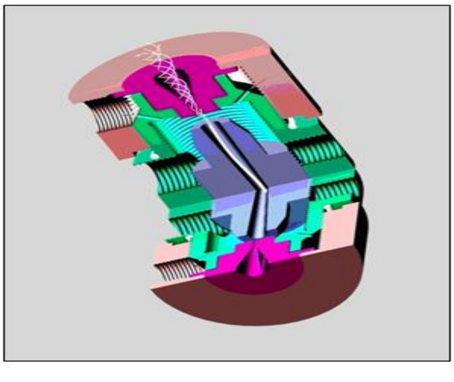


Figure 4-3D Cut cross sectional view of the of single jet nozzle no 12 using AUTO CAD 2006

3.1 Designs and Specification of Nozzle

The single jet nozzle consists of Air inlet chamber, Wrapper fiber chamber, False twist chamber and Fasciated yarn chamber.

Air inlet chamber consists of an air inlet pipe, air compressor, air drier and air pressure regulator. At the entry point of the inlet chamber, a circular 6 mm opening with threading to fix the air inlet pipe was designed. The other end of the pipe was connected to the air drier and air compressor with air pressure regulator. The main function of this chamber is to distribute the compressed air uniformly to air feed orifices. Figure 5 shows the dimensions of the Air inlet chamber.

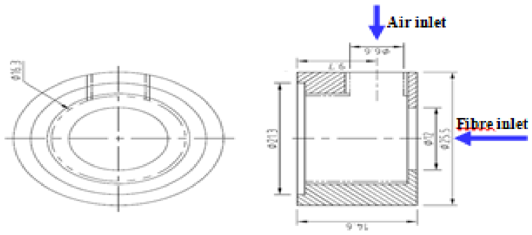


Figure 5 Specification of air inlet chamber

False twist chamber was designed by providing three air slots drilled at an angle of 45^{o} (120^{o} apart from each other) which are equally spaced with 0.75 mm diameter. Figure 6 shows the top view of the false twist chamber. These air slots are off–set with respect to the centre of the chamber to create air vortex at the top of fasciated chamber's hollow spindle. Similarly four more fibre chambers have been designed at different air fed angles of 50^{o}, 55^{o}, 60^{o} and 65^{o} so as to analyze the performance of chamber by optimizing the air fed angle. The air fed angle is an important critical parameter which controls the fibre loss. Figure 7 shows the cross sectional views of false twist chamber dimension

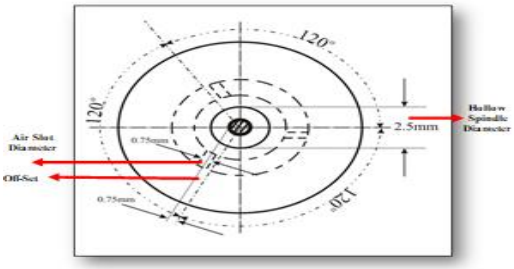


Figure 6 False twist chamber top view–Off set to create air vortex

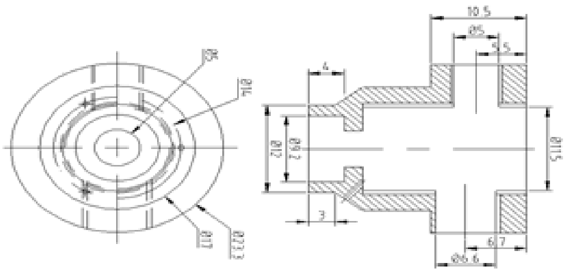


Figure 7 Specification of false twist chamber

Fasciated yarn chamber was designed with a tapered shape at the tip in such a way that the air vortex was developed which is responsible for the yarn formation. The inner hollow spindle was designed with a top diameter of 2.5mm and gradually reduced to 1.5mm. The outer bottom portion of the chamber was threaded so as to maintain the position of the hollow spindle according to the different air fed angles of 45°, 50 °, 55 °, 60° and 65 °. Figure 8 shows the Specification of fasciated yarn chamber.

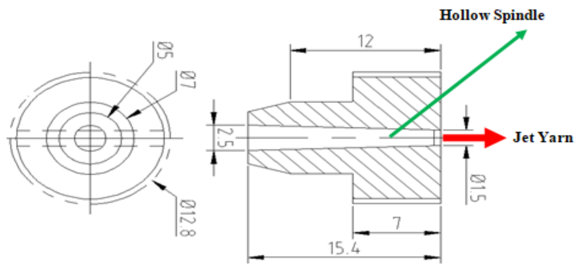
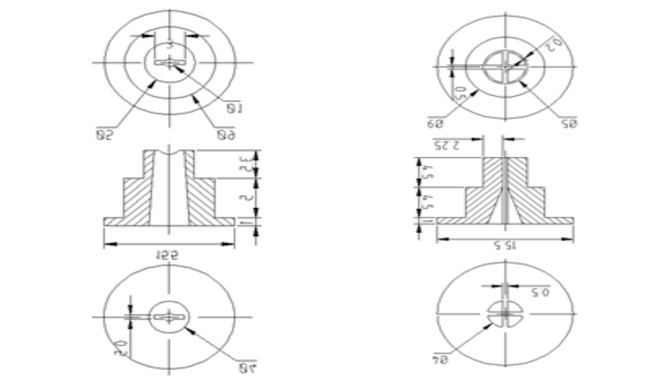


Figure 8 Specification of fasciated yarn chamber

Wrapper fiber chamber was designed in such a way that the air vortex should not propagate from the false twist chamber into the wrapper fibre chamber. This design aspect of the wrapper fibre chamber enables to achieve the feeding of parallel fibre to the air vortex zone. The core of the wrapper fibre chamber is round shaped at the top and ends with rectangular shape. This is done using the circular opening of 5 mm diameter at the top, which was tapered and is reduced to a rectangular shape of 1 mm x 3 mm (called as 'RWFC' type) – shown in Figure 5.2. Similarly, another model of wrapper fibre chamber was designed with four inner flanges which were equally spaced (called 'IFWFC' type) –shown in Figure 5.2. Figure 9 (a) and (b) shows the Specification of wrapper fibre chamber in both types



(a)Type RWFC*(rectangular shape) **(b)Type IFWFC**(inner flanged)**

Figure 9 Specifications of wrapper fibres chambers

The fabrication of this wrapper fibre chamber work was carried out under the requirements such as air engineering applications to form adequate wrapper fibres, with minimum fibre losses and fibre band width processing requirements. In the nozzles No.12 to 21, the formation of wrapper fibre was successful and was viewed in the scanning electron microscope and Leico microscope. The yarns are produced with satisfactory strength. In this nozzle, four divisions have been made at the bottom of the wrapper fibre chamber. These divisions will carry the wrapper fibres till the air vortex zone, which increases the number of wrapper fibres in the yarn construction, and this in turn leads to the increase in yarn strength.

3.2 Design and Development of Single Head Single Jet Spinning Unit

Performance analysis of all 18 developed nozzles for this research work was carried out using the above 'Single head single jet spinning unit'. In Single head single jet spinning unit the necessary modifications were carried out to incorporate the servo motor for the drafting zone, to achieve high draft range of 10-250 and delivery speed of 150 m/min. The developed nozzles were appropriately fixed at the delivery zone of the drafting system. The withdraw roller and winding drum assembly were fabricated and assembled on the 'Single head single jet spinning unit'. In Single head single jet spinning unit the necessary modifications were carried out to incorporate the servo motor for the drafting zone, to achieve high draft range of 10-250 and delivery speed of 150 m/min. The developed nozzles were appropriately fixed at the delivery zone of the drafting system. The withdraw roller and winding drum assembly were fabricated and assembled on the 'Single head single jet spinning unit'.

Figure 10 shows the line diagram of 'Single Head Single Jet Spinning Unit'. It consists of Nozzle Zone, Drafting Zone and Winding Zone. Figure 11 shows the Photographic view of the 'Single Head Single Jet Spinning Unit'. It consists of Nozzle Zone, Drafting Zone and Winding Zone. The position of withdraw roller assembly and the single jet yarn position also shown in same Figure. The position of the servo motor, single yarn package, air regulator knob with the air pressure indicator and dial gauge also shown in this Figure.

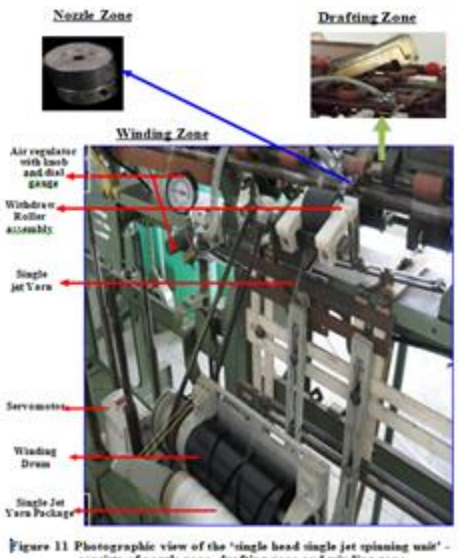


Figure 11 Photographic view of the 'single head single jet spinning unit' - consists of nozzle zone, drafting zone and winding zone

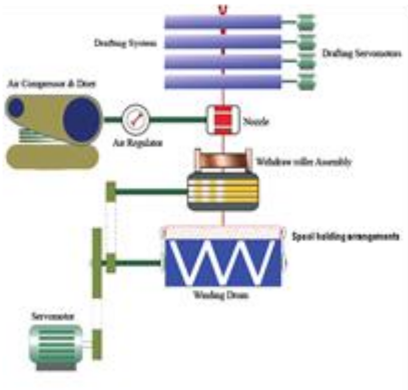


Figure 10 Line diagram of the 'single head single jet spinning unit'

3.2.1 Drafting Zone

The four over four WST UTM 620 drafting system has been used. Since sliver to yarn spinning require high draft range up to 250, the four servo motors for each bottom roller have been incorporated in drafting zone as shown in Figure 11, to achieve the high draft range of 10-250 with the delivery speed of 150 m/min. In the air jet spinning, the width of fibres strand coming out from the drafting zone should be in the spread form.

3.2.2 Nozzle Zone

As shown in Figure 11, the yarn forming zone consists of nozzle holding arrangement to position the nozzle and compressed air zone. The nozzle is properly fixed in such way that it is close to the drafting system and also in-between drafting zone and withdraws roller assembly. The compressed air zone consists of air compressor (ELGI make, Model HV25120) with capacity of 120 cubic feet per minute with air storage capacity of 1000 liters air tank with drier and air regulator. Using the air regulator the different air pressure from 1kg/cm^2 to 6 kg/cm^2 can be maintained and supplied to the nozzle.

3.2.3 Winding Zone

The winding zone consists of withdraw roller assembly, winding drum with spool holding arrangements and servo motor with driving mechanism which are shown in Figure 2.1. Withdraw roller assembly is to with draw the yarn from the nozzle zone and the supplied to the spool. To perform smooth winding and yarn tension, with - draw roller speed was synchronized with the front roller surface speed using the servomotor. The tension draft between front roller and the with draw roller assembly should be selected according to the sliver fed and roving fed 40s Ne cotton, 50s Ne viscose and 60s Ne polyester single jet yarns.

The tension draft between front roller and with draw roller can be varied between 0.95 – 0.99 through the servo motor and the driving unit mechanism. The different tension draft for the different materials were based on the length contraction occurred between front roller and out let of the nozzle due to wrapper fibre formation. The driving arrangement for the winding drum is shown in Figure 11. The yarn from withdraw roller assembly is wound on the spools which is positioned above the winding drum of 21/2 turns and 79 mm diameter of Bakelite drum.

4 Conclusions

The design and development of single jet nozzle was carried out in three phases. In the first phase, 11 Nozzles were developed with different dimensions. In the second phase five nozzles were developed in Inner flanged type wrapper fibre chamber with various air fed angle such as 45^o, 50 ^{o}, 55 ^{o}, 60^o and 65 ^{o}. In third phase five nozzles were developed in Rectangular shape type wrapper fibre chambers with various air fed angle such as 45^o, 50 ^{o}, 55 ^{o}, 60^o and 65 ^{o}. Based on trial runs, nozzles used in Phase I (Nozzle no 1 to 11) performed poorly when compared to second phase (Nozzle no 12, 13, 14, 15, 16) and third phase (Nozzle no 17,18,19,20,21) nozzles. Hence the remaining ten nozzles of second phase and third phase were taken up for further research work.

A ‘Single head single jet spinning unit’ has been designed and fabricated. This unit consists of a drafting zone, an air jet nozzle zone and a winding zone. With the help of servo motors

4/4 drafting system was synchronized and it was designed to provide draft of 10-250 and delivery speed up to 150 m/min.Further design changes can be made in the ‘single head jet spinning unit’ to increase the delivery speed of the unit up to 400 m/min and their yarn characteristics can be analyzed.

Acknowledgement

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