Turbo jet engine nozzle design optimization to reduce noise

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Abstract. An attempt has been made through this research work for developing single air jet nozzles and the production of single jet yarns using newly developed single head single jet yarn spinning unit. The fiber losses and end breakages during the production of sliver fed and roving fed 40s Ne cotton, 50s Ne viscose and 60s Ne polyester single jet yarns were observed in designed 21 nozzles. Regular ring yarns, Suessen regular compact yarns and newly introduced Suessen D-slot compact yarns, Murata air jet yarn and Murata air vortex yarns were produced and compared with single jet yarns. The design and development of single jet nozzle was carried out in three phases in this research work. The developed nozzles consist of air inlet chamber, wrapper fiber chamber, false twist chamber and fascinated yarn chamber. In the first phase, 1-11 Nozzles were developed with different dimensions. In the second phase 12-16 nozzles were developed with Inner flanged type wrapper fiber chambers in various air feed angle such as 45o, 50o, 55o, 60 o and 65o. In third phase 17-21 nozzles were developed with rectangular shape type wrapper fibre chambers in various air feed angle such as 45o, 50o, 55o, 60 o and 65o.Using e xperiment and slip-up principle, trails were conducted using above 21 developed nozzles. Single head single jet spinning unit has been designed and developed. It consists of drafting zone, air jet nozzle zone and winding zone. With the help of servo motor arrangements and 4/4 drafting system, it was designed to provide the draft range of 10-250 and to run the unit up to 150 m/ min. Developed nozzles were critically analyzed and significance of sliver feeding over roving feeding using 40s Ne cotton, 50s Ne viscose and 60s Ne polyester yarns were analyzed. Through the various developed nozzles, design parameters such as two different wrapper fibre chambers, five different air feed angle and five air pressures totally 300 samples were produced.

1. Introduction

Qualities of spun yarn are for the most part impacted by a few factors, for example, fiber properties, kind of strands, turning technique, course of action of filaments in the yarn and the procedure parameters of yarn producing exercises. Among all turning advances, the ring- turning is still broadly utilized for spun yarn generation. Ring turning gives genuine winding of strands by ethicalness of the pressure control connected on the filaments from the minute they leave the drafting framework to the minute they enter the bending zone. It is for sure the main turning framework that is fit for embeddings completely genuine bend. Ring turning speaks to the best alternative regarding using yarn structure to contribute successfully to texture structure and texture execution. It is the best framework in meeting basic changes in perspective of the present item run many-sided quality. It is likewise the most costly framework as demonstrated by its generously bring down generation rate contrasted with other turning frameworks, and the requirement for all the more exorbitant planning prior and then afterward turning (Roving and Winding Processes). The development in the ring spinning is focused towards the modifications in the ring spinning system like minimization of spinning triangle to improve the quality and production. This modification is known as compact or condensed spinning. Many developments are under progress in this field by various machinery manufacturers, applying any one of the principles like pneumatic compacting or magnetic compacting. Generally in the spinning industries the above compacting principles were adopted only for the manufacturing of "Combed Compact Yarn". There is a scope to focus the Research and Development activities on the manufacturing of "Carded Compact Yarn". Between the 1950s and 1980s, innovative spinning methods like rotor spinning and friction spinning were introduced into the field. These technologies were mainly suitable for coarse yarns up to 30s Ne count. Rotofil single jet spinning system came into the field in the early 70s. The main limitation of this system was poor yarn strength when compared to ring spinning system. Hence the commercial viability of this method was limited. Murata Jet spinning entered the market in the mid eighties as a new technology to produce yarns ranging from Ne 40s to 80s, particularly for polyester staple fibers. The functions of the twin nozzles in Murata Jet spinning are to twist the fibres by the first air jet nozzle and then the fibres are untwisted by the subsequent second nozzle. Ultimately, it produces core and wrapped structured yarn. When compared to regular ring spinning system, it claims high productivity at lesser labour cost and power cost by the elimination of roving and winding process. The only limitation in this system was reduction in yarn strength of 10 to 15% when compared to regular ring spun yarns.

2. MVS yarn properties in comparison with other yarns

Aung Kyaw Soe (2004), Huseyin Gazi Ortlek (2005) studied the Structure and Properties of MVS Yarns in Comparison with Ring Yarns and Open-End Rotor Spun Yarns. He compared these in a schematic diagram of the yarn structure as shown in Figure 2.3. No significant evenness differences exist in the three kinds of yarns, except for a higher frequency of thick places and neps in the MVS yarn. The hairiness length (1mm) for the MVS yarn was similar to the rotor yam and lower than the RS yarn. For the hairiness length (3 mm), MVS yarn hairiness is much lower than the other two kinds of yarns. The reason for this low hairiness of MVS yarn is the thin layer of wrapper fibres, which prevents the main yarn body from forming wild fibre loops along with yarn axis.

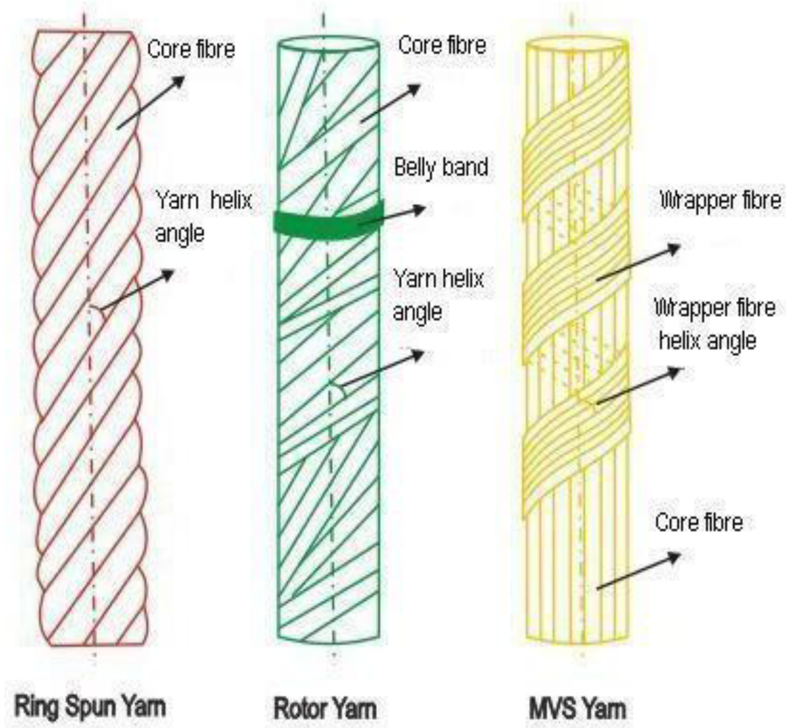

Figure 1. Schematic diagrams of the yarn structures

The yarn tenacity value of ring yarn is higher than that of rotor yarns and MVS yarns due to the lack of fibre parallelization, which causes a non-uniform load distribution. With regard to MVS yarns, the twisted fibre core of ring yarn as opposed to the non twisted core of the MVS yarn creates a stronger bond between the fibres. These fundamental structural effects cause the higher tenacity value of ring yarn compared with MVS yarn. MVS yarn is the bulkiest of the three kinds of yarns by the existence of loose wrapper fibres. They are formed by swirling air around the spindle under no tension and also by the creation of loops of wild fibres.

Migration in MVS was dealt with by Tyagi (2004) and Guldemet Basal (2006). The images captured during the analysis of yarn structure suggest that the fibre migration in vortex yarns differs from that in both air-jet and ring yarns. In vortex spinning, fibres emerging from the front rollers are sucked into the spiral orifice at the inlet of the air jet nozzle and move towards the tip of the needle protruding from the orifice. In the meantime, these fibres are subjected to a whirling air flow and receive twist. In air jet spinning, only the edge fibres become wrapper fibres.

Most of tracer fibres first showed core fibre characteristics, lying parallel to the yarn axis and then wrapper fibre characteristics, being helically wound onto the core. Guldemet Basal (2003) compared the properties of MJS and MVS yarn properties. MVS yarns found better tensile and elongation properties compared with the MJS yarns. The main difference between the air jet and vortex yarn is the number of wrapper fibres which is much higher in vortex yarns. Fibre processing laboratory, Cotton Incorporated USA 2000 critically analysed the comparison of performance of short fibre content on ring and MVS systems in cotton yarns. Stuart Gordon (2001) dealt with the effect of short fibre and nep levels on MVS efficiency and product quality on different ginning conditions of cotton yarns.

2.1 COMPACT SPINNING SYSTEMS: Compact spinning is a modification in regular ring spinning process which has special advantages, and can be used for short, medium and long-staple fibre spinning. Many research works have been carried out in this area. The Compact yarn has better fibre arrangements in the yarn structure with minimum peripheral fibres and with a better twist distribution (Kampen 2000, Meyer 2000, Stalder 1995, Guldemet Basal and William Oxenham 2006, Ganesan and Ramakrishna 2006, Morton 1956). In an interesting finding from another article, the author has critically analyzed the yarn similarities, structural differences and mechanical properties of regular ring yarn and compact yarn produced using medium staple fibres. Minimal turning strategy has been utilized for the long filaments moreover. A work done by Pinar Celik et al (2004) on 100% fleece, 45/55 fleece/polyester, 50/50 fleece/acrylic and 100% acrylic yarns appears in detail the properties and their applications. Many endeavors have been done so, medium and long filaments. 100% cotton short staple strands are utilized as a part of brushed smaller turning framework, while little R&D work has been completed on checked compacting yarn.

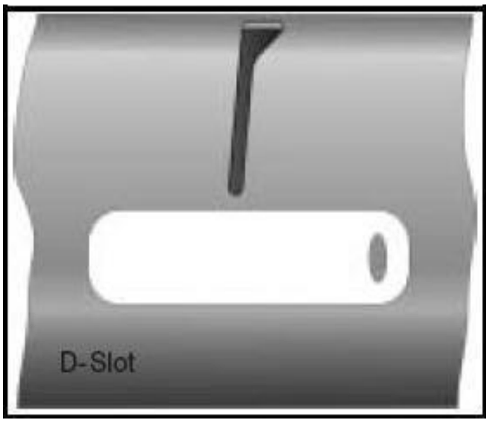

Figure 2. Suessen‟s D-Slot compact systems

Typically brushed meandering is utilized as a part of consistent compacting strategy. Compacting of checked meandering has all the more short strands when contrasted with brushed wandering without turning triangle, which is one of the intriguing marvels. In checked minimal yarn arrangement, strands are consistently situated and furthermore compacted into the yarn hub at the conveyance purpose of the drafting framework. Accordingly, the checked conservative yarn can guarantee better constancy, lengthening, and bushiness properties than normal ring checked yarns, which are the basic qualities for the better working execution in the consequent procedure. In minimized turning framework, the enhanced fiber joining, bring down end breakage and lessened lighten are the a portion of the elements to deliver top notch yarn in regard of furriness, equality and elastic properties. In

Suessen compacting framework, the smaller is accomplished by fiber transport through the punctured cross section and air drawn through slanted openings of the suction tube. As of late Suessen presented a novel idea of D-space (as appeared in Figure 2.4) which is exceptionally intended for the checked minimized yarn.

2.2 YARN STRUCTURAL ANALYSIS: Yarn structure assumes a key part in deciding the yarn physical properties and the execution attributes of yarns and textures. The most ideal approach to ponder the inner structure of the yarn is to inspect the course of action of single filaments in the yarn body and dissect their relocation in transversely and the long way forms. This requires visual perception of the way of a solitary fiber in the yarn. Since a fiber is moderately a little component, some particular procedures must be used for its perception. With a specific end goal to play out this assignment, past scientists created two distinct procedures.Tracer fiber method: This procedure includes drenching a yarn which contains a little level of colored filaments, in a fluid whose refractive file is the same as that of the first undyed strands. This makes the undyed filaments vanish from see and empowers the perception of the way of a dark colored tracer fiber under a magnifying instrument. Colored strands added to the crude stock before turning go about as tracers. Morton and Yen presented this strategy (Morton and Yen 1952)Cross sectional technique: In this strategy, implanting medium secures the filaments their unique position, at that point the yarn is cut into thin areas and these segments are considered under magnifying instrument. As in the tracer fiber procedure, the yarn comprises of for the most part undyed strands and a little extent of colored filaments with the end goal that there is close to one colored fiber in any yarn cross- segment.Normal smaller turning was perceived as an unrest of ring turning as of late. This innovation is asserted for the prevalent quality and better crude material usage (Kampen 2000, Meyer 2000 and Stalder 1995). The standard conservative turning framework creates an alternate yarn structure when contrasted with normal ring yarn structure. Despite the fact that many research works have been done on the properties and appearance of minimized yarn, just a couple of research works have been done to think about the inward structure of the reduced yarn (Guldemet Basal et al 2006, Ganesan and Ramakrishna 2006). The impact of wind on fiber relocation for ring and rotor yarns has been examined by many research laborers (Morton 1956, You Huh et al 2002, Hearle et al 1965, Salhotra et al 1981 and Pillay et al 1975).

3. Materials and methods

3.1 Single Jet Nozzle

In the designing of air jet nozzle, the following aspects were considered.

The raw material for designing the nozzle should have higher wear-resistance.

All the dimensions of the nozzle should be well within narrow tolerance limits which are very stringent and needs high technology equipment and tools.

The air feed angle nozzle should have very high dimensional accuracy so as to work perfectly with fibers and pneumatic air.

For design and development of nozzle, contour drawings were made using AUTOCAD 2006 and a wooden cut section model has been made for perfect designing of the nozzle. Aluminum alloy of grade 6061 has been selected to fabricate the nozzle. The nozzle No.1 to 11 (shown in Table 4.1) has been fabricated using the above aluminum alloy and trials were conducted.

After completing the first phase trials, it is concluded that nozzle 12 to 21 (shown in Table 4.2) are suitable for subsequent research work. For these nozzles Aluminum alloy of grade 7075 has been selected and 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.

3.2 Single Head Single Jet Yarn Spinning Unit

The single head single jet spinning unit has been fabricated to carry out the research work which consists of high draft zone, air nozzle zone and winding zone. Performance analysis of all 21 developed nozzles was carried out using the above „Single head single jet spinning unit". The servo motor has been incorporated for the drafting zone, to achieve high draft range of 10-250 and delivery speed of 150 m/min. At the delivery point of the drafting zone the developed nozzle has been fixed. The withdrawal roller and winding drum assembly were positioned below the nozzle zone.

3.3 Optimization of Nozzle Design Parameters Shanker 6 cotton, 1.2 denier x 38 mm viscose staple fibers and for 1.2 denier x 38 mm polyester staple fibers were used as raw material for this work. The following single jet yarns were produced using both sliver feed and roving as feed material for 40s Ne Cotton,50s Ne Viscose and 60s Ne Polyester. Three passage draw frame sliver hank of 0.24 were prepared for all materials namely cotton, viscose and polyester for the production of sliver fed single jet yarns. For the production of roving fed single jet yarn, the roving hank of 1.6 with low twist multiplier of 0.4 was produced from the simplex machine.

3.4 Comparison of Characteristics and Structure of Single Jet Yarn with Other Spinning Systems

The 40s Ne single jet cotton yarns were produced and compared with regular ring yarn, Regular Suessen compact yarn and Suessen D-slot compact yarn. 50s Ne single jet viscose yarn was produced and compared with yarns of the same count produced, using regular ring yarns and Murata air vortex yarns. Similarly, 60s Ne single jet polyester yarn was produced and compared with ring yarn and Murata air jet yarns.

Shanker 6 cotton, 1.2 denier x 44 mm viscose staple fibers and 1.2 denier x 44 mm polyester staple fibers were used as raw material for this work. Three passage draw frame sliver hank of 0.24 was prepared for all materials namely, cotton, viscose and polyester which were used as feed material for the production of single jet yarns, Murata vortex yarns and Murata jet yarns.

For the production of Cotton regular ring yarn, Suessen regular compact and Suessen D-slot compact yarns, roving hank of 1.6 bobbins was produced from the simplex machine. The bobbins were processed in regular ring frame for the production of ring yarn. The same ring frame was converted for Suessen"s compact system and regular compact yarn was produced. From this Suessen compact ring frame the D-slot suction tubes replaced with regular suction tubes were used for regular compact yarns. From the D-slot compact ring frame, D-Slot compact yarns were produced. The Figure 3.1 shows the line diagram of the Suessen"s regular slot and D – slot suction tubes used for this part of the work. The cotton slivers were processed in the single head single jet spinning unit for the production of single jet yarns. For production of Murata vortex spun yarns, the MVS 861 model machines were utilized and for Murata jet yarns, MJS 802H model machines were utilized.

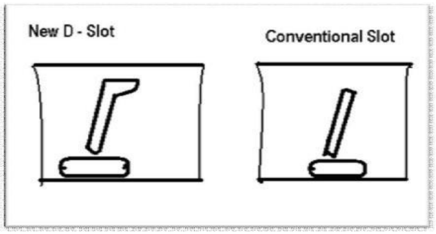

Figure 3. Line diagrams of the Suessen"s regular slot and D –slot suction tubes

3.5 Fiber Loss and End Brakeage study

The sliver feed for the production of single jet yarn is monitored online during the material processing in the developed single head single jet spinning unit. A platform type electronic balance is used to measure the amount of material feed to the spinning system. This Electronic weighing balance has a platform where the sliver can be placed above. So that we can easily monitor the rate of material feed on each study. The amount of yarn delivered is monitored by another electrical weighing balance. The difference in weight of the fed sliver material and produced single jet yarn gives the amount of material loss during the sample of yarn production. As like sliver fed, fibre loss % are estimated for the roving fed by weighing the roving bobbin before and after each sample of yarn production.

3.6 Flow Charts for Experimental Plans

Figure 3.2 shows the optimization of nozzle design parameters to produce 40s Ne single jet cotton yarns, 50s Ne single jet spun viscose yarns and 60s Ne single jet polyester yarns. The nozzle design parameters and their variations in the above nozzles are wrapper fibre chamber two types, air feed angles four types and four different air pressures. In total, 192 samples of single jet yarns were produced and their quality characteristics were critically analyzed using Multi variant ANOVA.

Figure 3.7 shows the flow chart experimental plan for comparison of characteristics and structure of cotton yarn produced from different systems such as Single jet spinning, Ring spinning, Suessen regular compact spinning and Suessen D-slot compact spinning. As shown in experimental plan, Carded 40s Ne cotton yarn was produced using four different spinning systems. standard procedures. The inter fibre migration characteristics such as mean fibre position, RMS deviation, migration intensity and yarn

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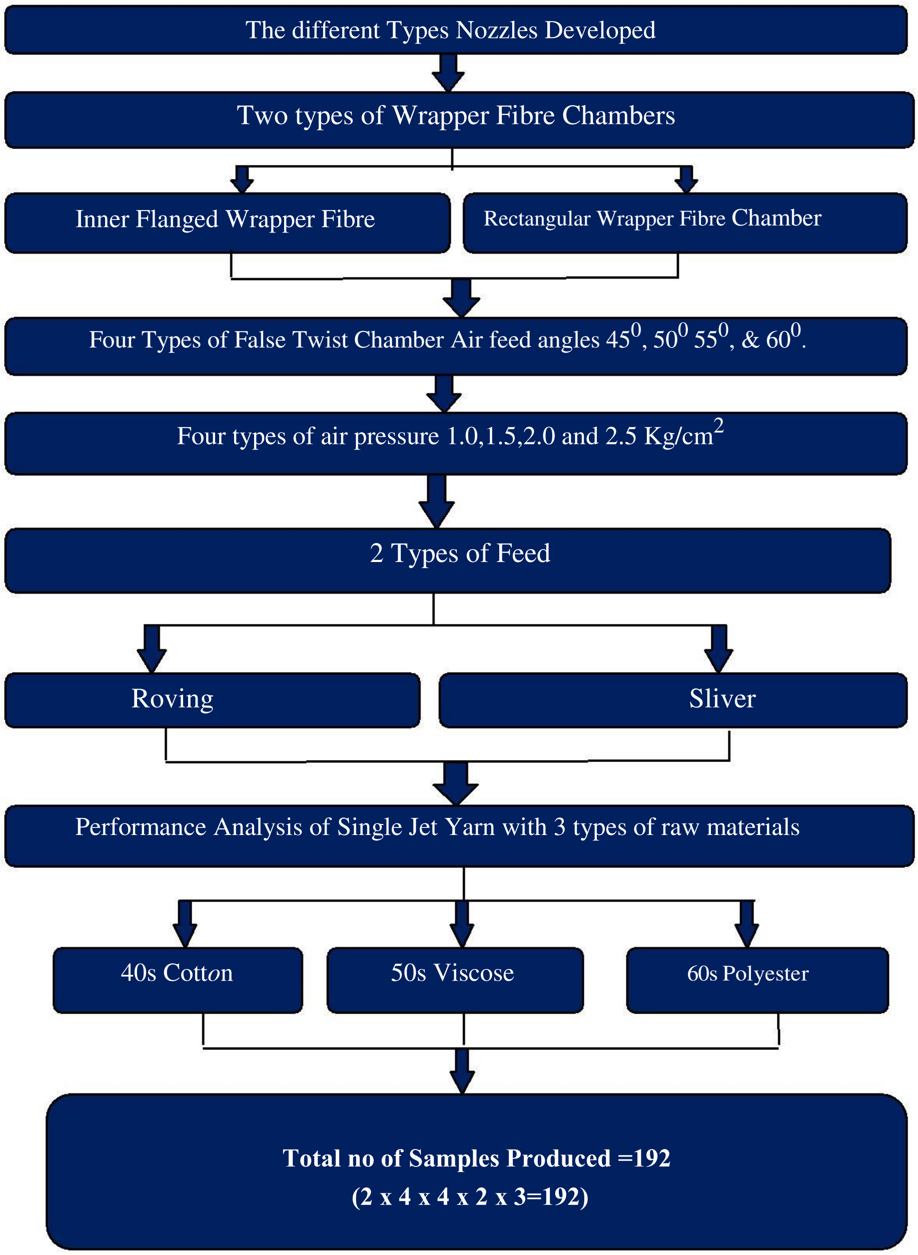

Figure 4. Experimental plans used for the performance analysis of the Developed nozzle

4. Design and development of single headsingle jet spinning unit: the drafting zone The four more than four WST UTM 620 drafting framework has been utilized. Since bit to yarn turning require high draft extend up to 250, the four servo engines for each base roller have been joined in drafting zone as appeared in Figure 5.1, to accomplish the high draft scope of 10-250 with the conveyance speed of 150 m/min. Noticeable all around fly turning, the width of filaments strand turning out from the drafting zone ought to be in the spread shape. In like manner the drafting procedure parameters were reasonably chosen. Table 5.1 demonstrates the diverse procedure parameters utilized for the generation of 40s Ne cotton, 50s Ne thick and 60s Ne polyester single stream yarns.

Table 1. Drafting parameters used in processing of sliver fed and roving fed

40s Ne cotton, 50s Ne viscose and 60s Ne polyester single jet yarns

S.No	Type of Yarn	40s Cotton Single Jet Yarns		50s Viscose Single Jet Yarns		60s Polyester Single Jet Yarns	
1	Type of feed	Roving	Sliver	Roving	Sliver	Roving	Sliver
2	Drafting System	WST UTM 620 Four over Four					
3	Delivery speed mpm	150.2					
4	Raw Material	Shanker 6		1.2D X 38 mm		1.2D X 38 mm	
5	Roller settings	36-36-49		40-44-49		46-48-52	
6	Top roller settings	40-36-47		44-44-47		50-48-50	
7	Top Roller loading in kgs	20,15,18 &18kgs		22,17,20 &20kgs		20,17,20 &20kgs	
8	Hank	1.6	0.24	1.6	0.24	1.6	0.24
9	Size of Rear Sliver Guide	10 x 4	20 x 9	12 x 5	20 x12	12 x 5	20 x12
10	Size of Middle Condenser	7 x 3	12 x 3	7 x 3	12 x 4	8 x 3	14 x 5
11	Size of Apron clip	3mm	5mm	2.5mm	6mm	2mm	6mm
12	Size of Front condenser	3	no	3	no	3	no
13	Actual Count	40.2	40.5	50.3	50.1	60.2	59.8
14	Total draft	25	166.7	25	166.7	25	166.7
15	Break draft	1.21	1.21	1.21	1.21	1.21	1.21
16	Middle Draft	2.5	2.5	2.5	2.5	2.5	2.5

17	Main Draft	8.31	55.1	8.31	55.1	8.31	55.1
18	Nozzle Used	All nozzles from 11 to 21 with air pressure of 1.0kg/cm2 to 3.0kg/cm2					
19	Tension draft maintained (Ratio between front roller surface speedto withdraw roller surface speed)	0.99	0.99	0.98	0.98	0.97	0.97

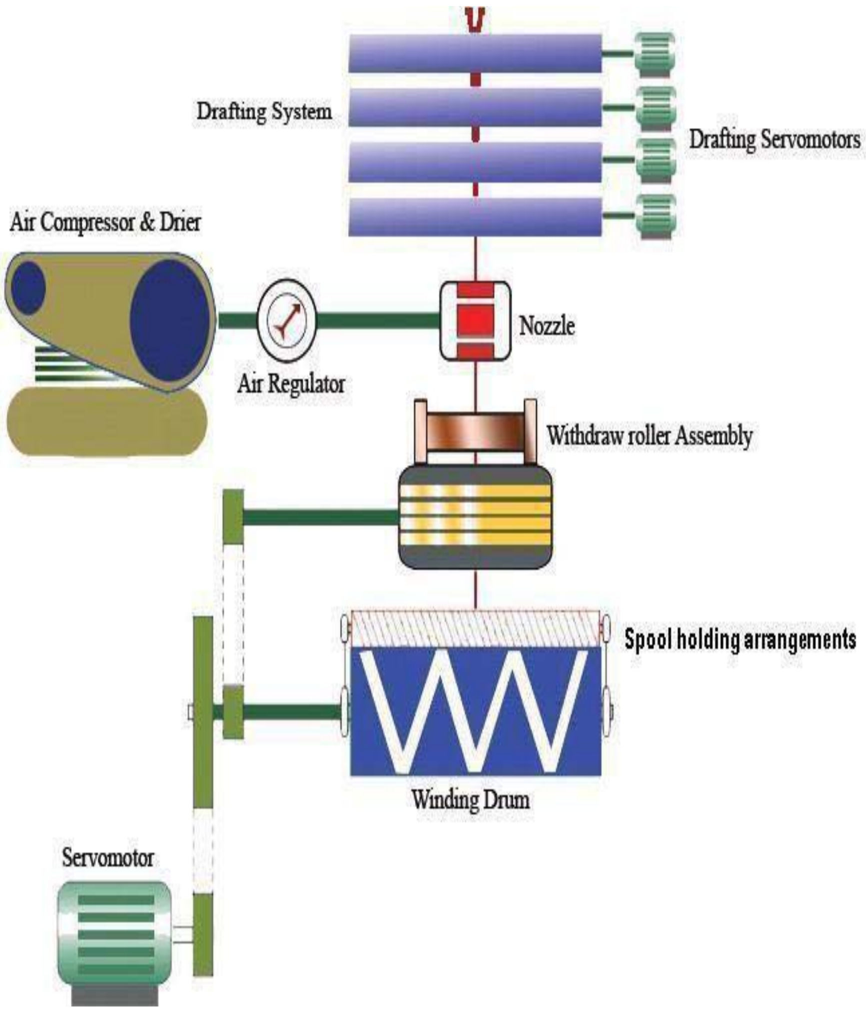

Figure 5. Line diagram of the „single head single jet spinning unit"

The drafting procedure parameter like best roller setting, base fluted roller setting, top roller stacking, size of back fragment control, size of center condenser, size of smock cut, size of front condenser, add up to draft, fundamental draft, center draft and break draft points of interest which are received for the creation of bit sustained and wandering encouraged 40s Ne cotton, 50s Ne thick and 60s Ne polyester single stream yarns are given in Table 5.1.

4.1 YARN FORMING ZONEAs appeared in Figure the yarn framing zone comprises of spout holding course of action to position the spout and compacted air zone. The spout is appropriately settled in such way that it is near the drafting framework and furthermore in the middle of drafting zone and pull back roller get together. The measurements of the spout and the nitty gritty depiction of the individual parts of the created spout, for example, air delta chamber, wrapper fiber chamber, false contort chamber and fascinated yarn chamber are managed in the Chapter 4. The packed air zone comprises of air compressor (ELGI make, Model HV25120) with limit of 120 cubic feet for each moment with air stockpiling limit of 1000 liters air tank with drier and air controller. Utilizing the air controller the distinctive pneumatic force from 1 kg/cm2 to 6 kg/cm2 can be kept up and provided to the spout.

4.2 WINDING ZONE The winding zone comprises of pull back roller get together, twisting drum with spool holding courses of action and servo engine with driving system which are appeared in Figure 5.1. The question of the pull back roller get together is to manage the yarn from the spout zone to the winding drum. Pull back roller speed was synchronized to perform smooth winding and yarn strain with the front roller surface speed utilizing the servomotor. The strain draft between front roller and the pull back roller gathering ought to be chosen by the bit nourished and wandering bolstered 40s Ne cotton, 50s Ne thick and 60s Ne polyester single fly yarns.

The strain draft between front roller and pull back roller can be differed between 0.95 – 0.99 through the servo engine and the driving unit instrument. As appeared in Table the strain draft is utilized for 40s Ne cotton is 0.99, for 50s Ne thick is 0.98 and for 60s Ne polyester is 0.97. The distinctive strain draft for the diverse materials depended on the length compression happened between front roller and out let of the spout because of wrapper fiber development. The driving game plan for the winding drum is appeared in Figure the yarn from pull back roller gathering is twisted on the spools which are situated over the twisting drum of 2.5 turns and 79 mm breadth of Bakelite drum.

5. Conclusion

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 feed angle such as 45o, 50o, 55o, 60 o and 65o. In third phase five nozzles were developed in Rectangular shape type wrapper fibre chambers with various air feed angle such as 45o, 50o, 55o, 60 o and 65o. 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. From the developed „Single head single jet spinning unit" jet yarns of 40sNe cotton, 50sNe viscose and 60sNe polyester were produced using sliver feed and roving feed. All the 10 nozzles of Phase II and III were used with 5 different air pressures of 1.0, 1.5, 2.0, 2.5 and 3.0 kg/cm2 to produce jet yarns.

6.References

[1] Artzt P. (1997), 'Inter Tex Bull', Vol. 2. pp. 41- 48.
[2] Artzt P. and Conzelmann M. (1989), 'Processing of Viscose and Modal Blended with Cotton on Air-jet-Spinning System', Melliand Textilber., Vol.70, pp.354.
[3] Artzt P. and Dallman H. (1989), 'The Potential and the Prospective for Cotton Yarns Manufactured According to the Pneumatic False Twist System', Melliand Textilber., (Eng. Edition), Vol.70, pp.131-133.
[4] Artzt P., Dallman H. and Ziegler K. (1985), 'Effect of Draft and Blend Ratio on the Properties of Air-jet SpunYarns', Chemifasern/Textile industry, pp.104.
[5] Artztand P. and Steinbach G. (1993), 'Influence of Force/Elongation Characteristics of Polyester Fibre on the Performance and Yarn
[6] Propertiesin Air-jet Spinning',Melliand Textilber., Vol.74,pp.297-E299.
[7] Aung Kyaw Soe, Masaoki Takahashi, Masaru Nakajima, Tatsuki Matsuo and Tatsumori Matsumoto (2004), ' Structure and Properties of MVS Yarns in Comparison with Ring Yarns and Open-End Rotor Spun Yarns' Textile Research Journal., Vol.74, pp.819 – 826
[8] Barella A., Bardi X., Castro L., Manich A.M. and de Castellar M.D. (1993), 'Approach to the Study of Yarn Hairiness Variability', Melliand Textilber., (Eng. Edition) Vol.74, pp.85-E86.