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A REVIEW ON REDUCTION OF AIR CONSUMPTION IN AIR JET LOOM: THE POSSIBLE SETTING POINTS

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ABSTRACT

Production is the main elements for a textile industry to keep pace with the present competitive marketplace. This leads researchers and machine manufacturers to invest millions of dollars to ensure new developments in process and machines. In weaving industry air jet loom is now the only machine that gives the highest productivity of almost all kind of yarns without any problem at higher speed compared to other existing looms. Due to using compressed air and electricity, the manufacturing cost in the air jet loom is high which makes it less preferable in some cases of producing simple weave construction. We have congregated the setting points of air - jet loom which could be considered as necessary devils for high consumption of air which makes it unprofitable for simple weave. In this article we mentioned the factors which directly or indirectly influence the consumption of air in the air – jet loom.

Contribution/ Originality: This study is one of very few studies which have tried to drawn together the possible setting points of air jet-loom responsible for high air consumption.

1. INTRODUCTION

Weaving machines are classified into four groups according to their weft insertion systems; shuttle, projectile, rapier and jet (i.e. air and water jet) looms [1]. The air jet weaving system is commonly preferred due to its high production speed compared to other systems. In air jet weaving machines weft is accelerated and taken through the shed by the flow impedance between the flowing medium (air jet) and the weft. The energy resulting from air pressure directed from the central air tank to the weaving machine changes into kinetic energy in the nozzle, which accelerates and delivers the weft in the differently formed air channels [2]. As pointed out by Githaiga, the weft insertion process in air-jet weaving is complicated because the yarn motion is determined by complex interactions between air drag and yarn properties. This peculiarity makes time and cost of the regulation high [3]. So air-jet weaving is the most productive but also most energy consuming weaving method [4]. As textile industry is an energy intensive industry, increasing the costs of energy is a challenge for both textile manufacturers and developers of textile production machineries [5]. In weaving the setting procedure is considerably more complex than for other types of processing machines [6]. Particularly, the setup procedure varies with the type of raw material and it involves a high number of variables such as flow rate of nozzles, pressure of nozzles or blow duration. The actual constraints, which limit their industrial applications, tightly linked to the problem of air-jet loom regulation, the low flexibility and the need of heavily specialized operators [7]. Academic research and literature on this theme is quite enormous. As the substantial consumption of air and compressor electricity, the increased manufacturing cost is one of the air jet looms disadvantages [8] we tried to drawn together the possible setting points of air consumption reduction in the air – jet loom in our article.

2. LITERATURE REVIEWS

For decades, scores of textile researchers and machine manufactures attempt to develop the construction of air jet weaving machine as it is very popular in the weaving industries because of its higher productivity and capable of texturing spun and cellulose filament fabrics which could not be produced by other looms [9]. Money-spinning air jet loom is vastly recommended by the producer as textile is a power exhaustive sector. So many articles are published on the theme of air jet loom productivity, air consumption, setting points, history, and sequential development in the construction. Few literary documents on this topic are enlisted in our article. Pioneer Adanur published his valuable research text such as he pointed out that the air jet weaving machines belong to the set of intermittent-operation of loom [10]. He also mentioned that the air pressure from the central air tank to the loom converted into kinetic energy in the nozzle, which push weft in the air channels differently shaped by loom types [11]. By maintaining the air pressure of the air jet loom along the main valve & relay valve drive time low air will be consumed without hampering product quality [12]. Poppe studied the air index and claimed that air consumption decreased as the yarn hairiness increased [13]. Tarabadkar indicated the importance of compressors on air consumption in spinning and weaving machines [14]. Some researchers studied the various loom parts such as the nozzle, reed, and valves to improve the filling insertion and reduce air consumptions and thus developed an optimum main nozzle design [15-17]. Mohamed and Salama studied the mechanics of the air-jet filling insertion and the nozzle design [18]. Picanol developed the air-index as a measure of weft yarn suitability for air-jet weaving also introduced a new relay nozzle design with 16 holes to reduce air consumption [19, 20]. Dornier developed a PIC (Permanent Insertion Control) system for permanent monitoring of the most important filling insertion elements [21]. Similarly, Sultex claims outstanding results with regard to compressed air consumption on L5500 looms with the new AWC (Active Weft Control) system [22]. Other loom makers also claim substantial reductions in air consumption following new developments in their designs [23, 24]. Özer Göktepe and Orcun Bozkan showed that weaving mills could obtain considerable savings in energy costs by working with single-holed relay nozzles having smaller hole diameter and by achieving the shortest possible blowing time adjustments on air-jet looms equipped with multi-holed relay nozzles, without any decrease in loom efficiency and performance [25]. Islam M.M., Hanifa A.M.A. showed that using low air pressure air consumption and cost of air-jet loom can be reduced [26]. Raj Kumar Khiani suggested some measures in his paper to reduce the air consumption in air-jet loom [27]. Even if air-jet weaving machines manufacturers and researchers have been continuously working on reduction of air consumption in their new design to overcome the negative aspect of high consumption of air and additional cost of compressor electricity until now there is still deficiency of reliable information on energy efficiency of compressed air for industries [28-33].

3. TERMS AND DEFINITIONS

Air Compressor –An **air compressor** is a device that converts power (using an electric motor, diesel or gasoline engine, etc.) into potential energy stored in pressurized air (i.e., compressed air) [34].

Air Filter – An apparatus designed to improve the quality of circulating air by filtering out impurities [35, 36].

Air Index value – A term designated to quantify the velocity of yarn in air as well as the deviation in velocity when tested on a diagnostic testing machine known as the Air Index Tester [37]

Arrival Time – Time required by the pick to travel the width of the loom during weaving. It is measured either by degree of rotation of crank or shed or by the amount of time [27].

Profile Reed – With the profile reed, the restriction on warp density also less severe than in the case of the confusor guide system. This is now widely used in the modern air jet weaving machines [38, 39].

Nozzles – A nozzle is a device designed to control the direction or characteristics of a fluid flow of air as it exits an enclosed chamber or pipe. In air jet weaving main nozzles and sub nozzles are used to control the passage of weft [15, 16].

Count – A numerical designation of yarn size indicating the relationship of length to weight. It is the measure of coarseness or fineness of the yarn [40, 41].

Pick –The yarns that run crosswise are called weft yarns and each thread in the weft is called a pick or filling yarn. A temporary shutdown of a weaving machine due to an error in filling yarn insertion is called filling or weft stop [42, 43].

Yarn Hairiness – A quantitative method of describing the surface roughness of cotton based spun yarn by counting the amount of broken fibres that protrude from the surface of the yarn, giving it a fuzzy appearance [40, 41].

Heddles – A looped cord, shaped wir0.e, or flat steel stripe with an eye in the centre through which a warp yarn is threaded so that its movement may be controlled during weaving [44]

4. HISTORY OF AIR JET WEAVING

Brooks (USA) was the first to insert the weft with air in 1914 [45] In 1929 Ballou patented the nozzle on the insertion side of the weaving machine, while he placed a suction nozzle and the receiving side [46]. One year later another patent was granted in which a number of auxiliary jets were incorporated to maintain the air stream and provide weft insertion [47]. The first commercial machine was the "Maxbo" based on Maxbo paaeboe's design [48]. After that the production of commercial air jet weaving machine is increased rapidly and machines are under constant development.

4.1. Some Insertion Condition Which Should be optimized

Research has been done to analyze factors that contribute to compressed air use, a major source of energy consumption, in air-jet looms. As the main energy consumed by compressed air following conditions of air jet weaving must be optimized….

i. Speed of air jet in the nozzle
ii. Keeping air jet along the reed
iii. Controlling nozzles
iv. Suction nozzle or stretch nozzle to straighten the weft
v. Weft accumulator and length measurement device
vi. Economical air supply at specified pressure and cleanliness [49]

4.2. Filling Insertion System in Air Jet Loom (Open Profile Reed)

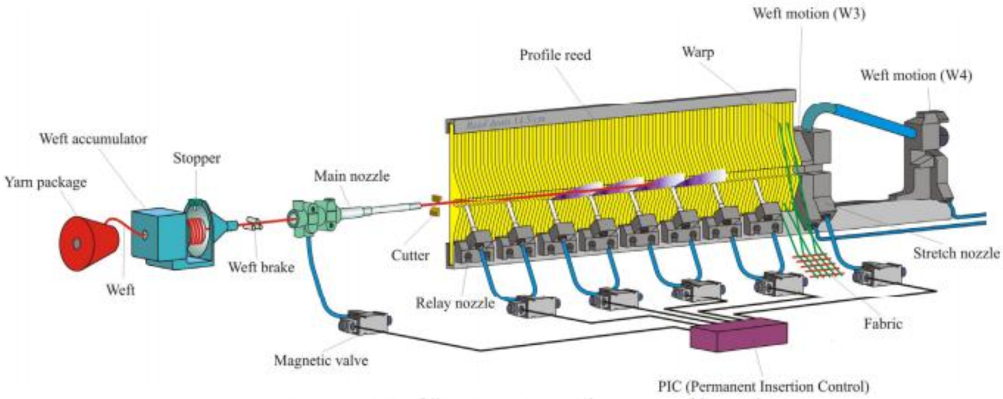

Fig-1. Weft insertion system of air-jet weaving loom [38]

5. COMPRESSOR DETAILS WITH WORKING METHOD

The device which converts power into potential energy stored in pressurized air. By one of several methods, it forces more and more air into a storage tank, increasing the pressure or air on it, is called air compressor. It is mainly used to produce moisture and dirt free air. Air cooler and water cooler air compressor are mainly used to supply air into the air-jet loom nowadays. Their figure with process flow and working method is given below [50, 51].

5.1. Working Method of GA75 Air Cooler Compressor

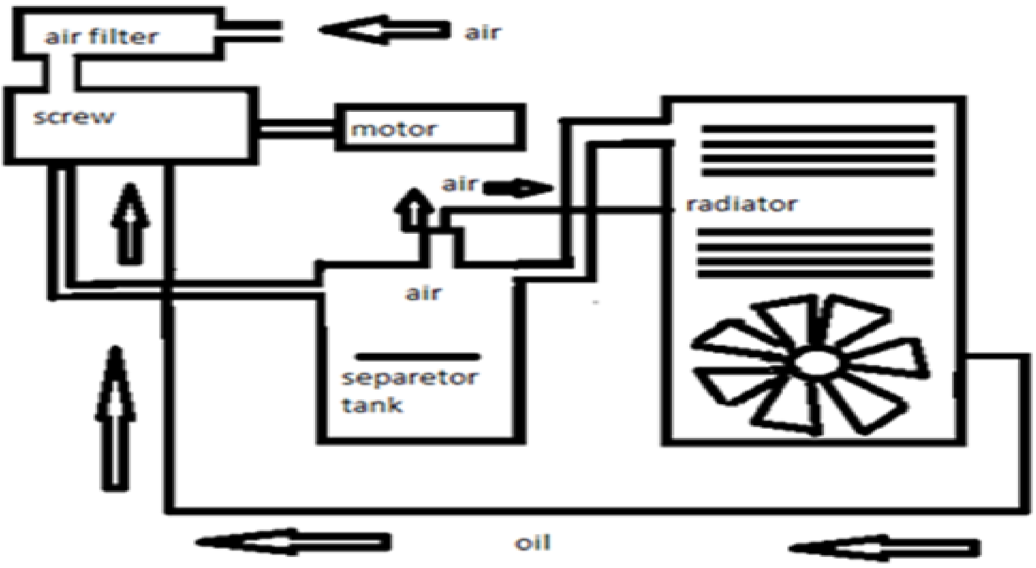

Fig-2. Process flow of GA75 air cooler compressor [50].

In this process the free air comes to the air filter with a low pressure where the impurities and dirt particles are removed from the air. The filtered air comes into the screw which contains a few amount of oil when the motor generates. Then air come into a separator tank after passing a inter cooler and then go to the radiator tank. Here the air is compressed foe producing compressed air by using high pressure generates. Then the produced compressed air is passed through after cooler and distributed through pipe lines to the loom [50].

5.2. ZR355 Water Cooler Compressor

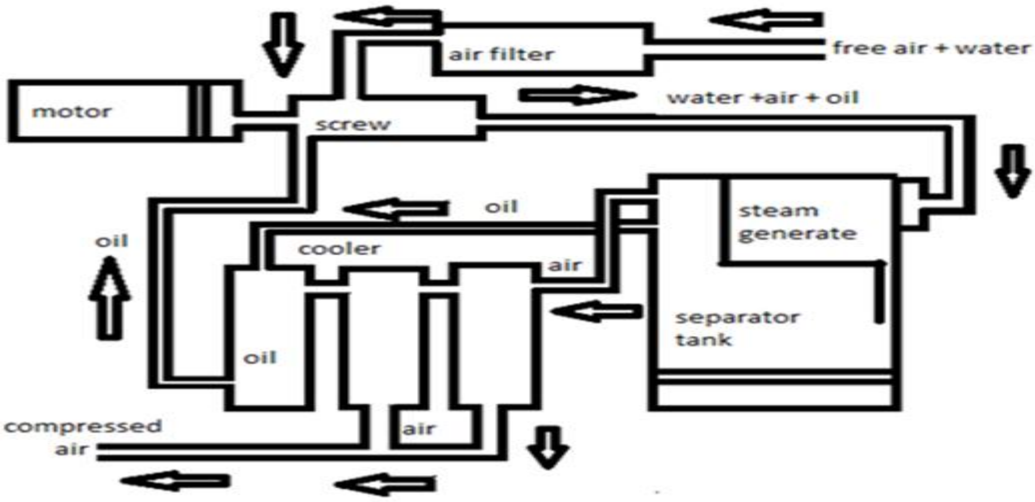

Fig-3. Process flow of ZR355 water cooler compressor [51].

5.3. Working Method of ZR Water Cooler Compressor:

At first, the motor is generated to rotate the screw and free air and water come into the filter where the dirt particles are removed. Then water and air come into the screw and the oiling unit supplies oil to the screw for the operation. After passing the screw they come into a tank which has a steam generator. It produced steam from the water. Then the steam air and oil passed through the separator tank which separates the air and oil into the cooling unit. After passing the cooling unit oil come back to the oiling unit and the air will compressed into the cooling tank and with contain a large amount of pressure it comes out to the pressure valve. This compressed air contains a large amount of relative humidity so that, a extra dryer is used to produce moisture free compressed air [51].

6. FACTORS AFFECTING AIR CONSUMPTION IN AIR-JET LOOM

6.1. Design of the Air Jet Weaving Machines

6.1.1. Type P and PN

One key feature of the machine is the unusual machine arrangement since the weaving plane is inclined 36^0; the batch is placed on the side of the warp beam. It is favorable if the weft is inserted n the centre line of the shed, possibly a long way from the fabric edge using a passive element, so-called confuser drop wires that are almost closed elements, but they are open at the top. On type P weaving machines the nozzle is fixed on the machine frame and the confuser drop wires are fixed on the swaying slay. Two types of confuser drop wires are used namely metal open confuser drop wires and closed plastic confuser drop wires. As plastic confuser drop wires have closing clappers creating an almost closed ring in terms of air flow, which make it possible for the weft stuck on the lower warp side to slip out of the confuser drop wires when the reed moves towards the fabric edge. Therefore at the upper part the air outflow from the drop wires significantly decreases-compared to the metal confuser [49, 52].

6.1.2. Air Jet Weaving Machines with Tunnel Reed and Relay Nozzles

It is possible to simulate industrial flow conditions in stationery reed position on electronically controlled weaving machines with tunnel reed and relay nozzles. However, only nozzles or type P and PN system do not meet the needs of weft speed and further increase in width due to high air consumption [49, 52].

6.2. Design of Compressor

The device which converts power into potential energy stored in pressurized air. By one of several methods, it forces more and more air into a storage tank, increasing the pressure of air in it, is called air compressor. It is mainly used to produce moisture and dirt free pressurized air. This pressurized air can be produced in different types of machines as below, [50, 51]

6.2.1. Air Cooler Compressor (GA75)

The air cooler GA75 compressor has an air cooling system which is moisture free. It is a screw type compressor and do not need much pressure and energy source. So that it have the features like low noise, low energy consumption, and also low maintenance charges [50]

6.2.2. Water Cooler Compressor (ZR 55)

On the other hand the water cooler ZR 355 compressor is rotary screw type compressor which needs so much pressure and energy for producing compressed air. The cooling water consumption rate is about 4.9 liter/s; so it needs extra dryer to produce moisture free air. It has a large noise level and it needs high maintenance charges [51].

Oil in air filtration system may cause expensive production slow down, downtime, spoilage, clog nozzles, stain the fabrics etc. Modern efficient air filters cannot guarantee 100% clean air though it is more efficient. On the other hand humidity causes corrosion in the air net and weaving machines thus leads to high power requirement, maintenance cost, clog nozzles and spoil fabrics in water cooler compressor. Thus it is critical for successful air jet weaving in selection of air compressor for reducing air consumption [36].

6.3. Air Pressure

The pressure of air for main nozzle is set according to count of weft yarn. But, it is not set same for all air jet loom as other factors like distance from compressor to weaving machine, elbows etc. Air consumption is directly proportional to air pressure therefore high air pressure leads to higher air consumption.

Sub nozzles are main components that consumes highest amount of compressed air. Air jet weaving machine do not work on optimum pressure. As humidity, air duct efficiency is not same thus same air pressure cannot be set even for same construction of fabric with all different models. Conventionally air pressure is directly proportional to the number of warp in the fabric width [27].

6.4. Design of Main Nozzle

By maintaining the air pressure of the air jet loom along the main valve and relay valve drive time low air will be consumed without hampering product quality [53]. At constant pressure, if main valve drive and relay valve drive duration are increased air consumption also increased. But, for constant loom setting air consumption is directly proportional to the air pressure [26].

6.5. Design of Sub or Relay Nozzle

Arrangement and design of sub or relay nozzle has a great effect on the weft insertion at low pressure. Sub or relay nozzles are arranged in groups of 4 or 5 nozzles and an electro-magnetic valve is attached to each group and the sub-nozzles of the same group jet simultaneously. For constant velocity and straight flow of weft yarn sub nozzles play the vital rule in air jet loom. An air jet loom requires 40-100 m^3/h of compressed air with about 0.6 MPa of air pressure for weaving fabric, depending on the yarn type, fabric type and loom speed [54].

6.5.1. Diameter of Relay Nozzle

Özer Göktepe and Orcun Bozkan investigated and found that replacing relay nozzles of 1.4 mm hole diameter with 1 mm hole diameter air consumption can be reduced by 21% and loom efficiency slightly increased [25].

6.5.2. Types of Holes in Sub-Nozzle

Rectangular holes, circular holes, elliptical holes, multi holes, two vertical holes and tapered hole. It has been observed that multi holes gives blowing angle stable at different pressure levels with 15% higher weft yarn insertion speed than single hole [8].

6.5.3. Number of Holes of Relay Nozzles

The multi hole relay nozzles guarantee a very stable blowing angle at different pressure levels where the single-hole nozzles need to be adjusted by hand. Due to the pre-given horizontal and vertical jetting angles, the multi-hole nozzle requires less space between the warp yarns, which prevents nozzle marks in fabric. The multi hole pattern allows also a more efficient air stream, thus delivering a better performance over single hole nozzles, giving up to 15% higher yarn speed for the same air consumption. Single-hole nozzles are recommended in case of a dusty environment or low air quality [55].

6.5.4. On the Basis of Air Guidance Method

i. Single nozzle with confuse
ii. Multiple relay nozzles with air guide
iii. Multiple relay nozzle with profile or tunnel reed

6.5.4.1. Blowing Times (Opening and Closing)

For producing a specific fabric construction optimum blowing time is set by the hit and trial basis and set for better efficiency. If blowing time is reduced gradually the quality and efficiency may faulty. But, experiment shows that short blowing time at which some weft cut and weft curling occurs, but air consumption reduced, though it may cause inadequate stretching of the filling by the stretch nozzle without drop in loom efficiency. Sub nozzles are the main air consumers of compressed air where 80% of compressed air is consumed [56]. As there is no optimum setting for air pressure in sub nozzles for different counts of weft yarn, hit and trial basis is the main base for the workers. Short opening and closing time ensure less air consumption where as long opening and closing duration leads to high air consumption if other factors are controlled properly [27].

6.5.4.2. Pick Insertion and Arrival Time

If the pick insertion begging to arrival time is short the speed of weft needs to be increased and air pressure should be high vice versa. Higher pressure is required to minimize the insertion time or increase in picking speed and thus leads to high air consumption [27].

6.5.4.3. Setting of Relay Nozzles

At the time of weft insertion through by air on the air-jet loom, the setting of relay nozzles should be perfect as it can affect the pick insertion mechanism. To control the weft air supply is restricted by valve associated with four or five relay nozzles. As air pressure will not be same, one pressure valve for one relay nozzle can be used to save air and weft arrival time keeping same air pressure [57].

6.6. Filling Insertion System

The filling is inserted pneumatically and a typical insertion system of relay nozzles and it is carried through the shed by compressed air flow. Jet timing is controlled from the beginning of main nozzle and synchronal controlling of relay nozzles. In air jet weaving weft is inserted in three ways such as single nozzle with confuser guides, relay nozzles with air guides and relay nozzles with profile reed [38].

6.7. Loom Setting

6.7.1. Count of Weft Yarn

As the yarn count becomes coarser, it becomes heavier due to increase in yarn mass, energy or the amount of air required to carry it through the shed is high [58].

6.7.2. Fabric Width

The fabric width means the distance that the weft yarn has to travel through shed. If the fabric width is increased, the air consumption is also increased and vice versa [55, 58].

6.7.3. Reed Count

If reed count increased there will be less space available for air to disperse through the dents thus less air will be consumed and vice-versa [55, 58].

6.7.4. Loom Speed

More picks have to be inserted through the shed per unit time if the loom speed increased. So, the requirement of air per unit time will be more. Loom speed is the second most significant factor affecting the air consumption [55, 58].

6.7.5. Pick Insertion Cycle

Pick insertion cycle or dwell period has direct relation with loom speed and loom width. More time required for weft yarn travel through shed more air will be consumed by main nozzles and relay nozzles [27].

6.7.6. Machine Stop and Running Position

It is observed that air-jet weaving machine at stop position when no primary or secondary motion is active still consumes air continuously. Also, leakage or other factor may lead this to more air consumption if not checked properly. During manufacturing of fabrics picking, cutting process and nozzles are the key parts that requires compressed air. Different models of machines may consume different amount of compressed air due to main nozzles pressure variation, sub nozzles pressure variation, opening and closing timing of sub nozzles, main nozzles and pick insertion time variations, number of weaving machine, distance of weaving machine from the compressor [27].

6.7.7. The Effect of Selvedge Pattern

It was found that no significant difference among the selvedge patterns in terms of air consumption but, less air was consumed by Dornier LW machines running at 600 rpm compared with running at 500 rpm. The fact of blowing time of the tuck –in devices may have influenced the result [27, 56].

6.7.8. Pneumatic Tuck-in Mechanism

It is based on holding and then tucking-in the filling end into the next shed using air. According to the selvedge pattern air consumption vary due to single or multiple filling ends tucked in. This tuck-in mechanism will add extra air consumption to the total consumption of the loom [25].

7. CONCLUSION

Technical solution to reduce the consumption of air in the air jet loom has become indispensable for the both parties machine manufactures and factory owners. As the air jet loom is highly preferable for its productivity the design of air compressor, design of the nozzle should be modified to reduce the consumption of air. Air pressure, blowing time, pick insertion and arrival time are considered to be important for the air consumption attenuation. From the review we have found that different loom setting points are accountable such as count of weft yarn, fabric width, reed count, loom speed, pick insertion cycle, machine stop and running position, the effect of selvedge pattern etc. for prominent air consumption. This article will be very supportive for the technologist who tries to modify the air jet loom to curtail the drawback of it recognized as high air consumption in the setting of loom.

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REFERENCES

[1] M. C. Kayacan, M. Dayik, O. Colak, and M. Kodaloglu, "Velocity control of weft insertion on air jet looms by fuzzy logic," *Fibres & Textiles in Eastern Europe*, vol. 12, pp. 29-33, 2004. *View at Google Scholar*

[2] I. Patkó and L. Szabó, "The study of the flow conditions of Air jet weaving machines," presented at the 10th International Symposium of Hungarian Researchers, Budapest Tech, 2009. November 12-14, 2009.

[3] J. Githaiga, L. Vangheluwe, and P. Kiekens, "Relationship between the properties of cotton rotor spun yarns and the yarn speed in an air-jet loom," *Journal of Textile Institute*, vol. 91, pp. 35-47, 2000. *View at Google Scholar | View at Publisher*

[4] A. Schröter and T. Holtermann, "Increasing energy efficiency of relay nozzles of air jet weaving at the institute of textile technology in Aachen, RWTH Aachen," in *Proceedings of the 14th Chemnitzer Textile Conference*, 2014, pp. 28-35.

[5] C. Grassi, A. Schröter, Y. Gloy, and T. Gries, "Increasing the energy efficiency of air jet weaving based on a novel method to exploit energy savings potentials in production processes of the textile industry," *Journal of Environmental Science and Engineering B*, vol. 5, pp. 26-34, 2016. *View at Google Scholar | View at Publisher*

[6] T. Osthus, E. De Weldige, and B. Wulfhorst, "Reducing set-up times and optimizing processes by the automation of setting procedures on looms," *Mechatronics*, vol. 5, pp. 147-163, 1995. *View at Google Scholar | View at Publisher*

[7] A. Brun, D. Corti, and A. Pozzetti, "The impact of the setting of air-jet looms on the fabric quality: An investigation," *International Journal of Quality & Reliability Management*, vol. 25, pp. 313-329, 2008. *View at Google Scholar | View at Publisher*

[8] M. EI- Messiry and S. Youssef, "An apparatus for measuring the sub-nozzle efficiency of air- jet weaving machine," *Indian Journal of Fibre & Textile Research*, vol. 35, pp. 358-360, 2010. *View at Google Scholar*

[9] A. Ormerod, "Air jet weft insertion: Present and probable future technical and economic performance" *Journal of the Textile Institute*, vol. 92, pp. 93-108, 2001. *View at Google Scholar | View at Publisher*

[10] S. Adanur and M. H. Mohamed, "Analysis of air flow in air-jet filling insertion," p. 124, 1994.

[11] S. Adanur and M. H. Mohamed, "Analysis of yarn motion in single-nozzle air—jet filling insertion. Part I," *Theoretical Models for Yarn Motion*, pp. 12-23, 1999.

[12] S. Adanur and T. Turel, "Effects of air and yarn characteristics in air-jet filling insertion part ii: Yarn velocity measurements with a profiled reed," *Textile Research Journal*, vol. 74, pp. 657–661, 2004. *View at Google Scholar | View at Publisher*

[13] T. Poppe, "The influence of rotor yarn properties on air consumption in air jet weaving," Master's Thesis, Institute of Textile and Process Technology, University of Stuttgart, 1995.

[14] S. A. Tarabadkar, H. M. Sharma, and D. H. Yadav, "Assessment of compressed air requirement for spinning and weaving machines," *BTRA Scan*, vol. 31, pp. 15-21, 2001. *View at Google Scholar*

[15] M. Ishida and A. Okajima, "Flow characteristics of the main nozzle in an air-jet loom part i: Measuring flow in the main nozzle," *Textile Research Journal*, vol. 64, pp. 10–20, 1994. *View at Google Scholar | View at Publisher*

[16] M. Ishida and A. Okajima, "Flow characteristics of the main nozzle in an air-jet loom part ii: Measuring high speed jet flows from the main nozzle and weft drag forces," *Textile Research Journal*, vol. 64, pp. 88–100, 1994. *View at Google Scholar* | *View at Publisher*

[17] S. Y. Jeong, K. H. Kim, J. H. Choi, and C. K. Lee, "Design of the main nozzle with different acceleration tube and diameter in an air-jet loom," *International Journal of Precision Engineering and Manufacturing*, vol. 6, pp. 23–30, 2005. *View at Google Scholar*

[18] M. H. Mohamed and M. Salama, "Mechanics of a single nozzle air-jet filling insertion system part i: Nozzle design and performance," *Textile Research Journal*, vol. 56, pp. 683–690, 1986. *View at Publisher*

[19] N. V. Picanol, "The air index, a new reference for yarn evaluation," *Picanol News*, pp. 8–11, 2001.

[20] N. V. Picanol, Picanol News. [Accessed 05-01-2017], pp. 17–27, 2006.

[21] Available: http://www.lindauerdornier.com/en/weaving-machine/a1-air-jet-weaving-machine.

[22] Available: http://www.itemagroup.com/en/products/airjet/a9500.

[23] Available: www.tsudakoma.co.jp/textile/english/product/1000.

[24] Available: https://www.toyota-industries.com/products/textile/shokki/index.html.

[25] O. Göktepe and O. Bozkan, "Study on reduction of air consumption on air-jet weaving machines," *Textile Research Journal*, vol. 78, pp. 816-824, 2008. *View at Google Scholar* | *View at Publisher*

[26] M. M. Islam and A. M. A. Hanifa, "Study on reduction of air consumption for air jet loom," *Institute of Engineering and Technology*, vol. 3, pp. 13-18, 2013. *View at Publisher*

[27] R. K. Khiani, M. H. Peerzada, and S. A. Abbasi, "Air consumption analysis of air-jet weaving," *Mehran University Research Journal of Engineering & Technology*, vol. 35, pp. 453-458, 2016. *View at Google Scholar*

[28] AMSG, "Compressed air systems market assessment", public service electric and gas pacific energy associates," Final Report Edison, NJ, USA, 2001.

[29] B. Joseph, "Compressed air supply efficiency," presented at the Conference on IETC, Houston, Southern California Edison, USA, 2004.

[30] B. Joseph, "Industrial compressed air supply system efficiency, California energy commission pier program," Consultant Report, 2004.

[31] M. Hasmandova, "Compressed air systems: Auditing and replacing air compressors," *Filtration & Separation, Elsevier*, vol. 45, pp. 41-42, 2008. *View at Google Scholar* | *View at Publisher*

[32] J. Holdsworth, "Conserving energy in compressed air systems," *Plant Engineering*, vol. 51, pp. 103-104, 1997.

[33] R. E. Terrell, "Improving compressed air system efficiency: know what you really need," *Energy Engineering*, vol. 96, pp. 7–15, 1999. *View at Google Scholar*

[34] Available: https://en.wikipedia.org/wiki/Air_compressor.

[35] Available: https://www.merriam-webster.com/dictionary/air%20filter.

[36] J. K. Arora, "*Modern weaving technology*. India: Abhishek Publication, Chapter-4," pp. 164-220, 2011.

[37] Available: www.picanol.com.cn/NR/rdonlyres/91264089-B920.../Fairindex01_07150dpi.pdf.

[38] S. Lóránt and S. László, "Weft insertion through open profile reed in air jet looms," *Tome X* , *Fascicule*, vol. 2, pp. 211-218, 2012. *View at Google Scholar*

[39] R. Shintani and A. Okajimi, "Air flow through a weft passage of profile reed an air jet looms," *Journal of the Textile Machinery Society of Japan*, vol. 54, pp. T9-T16, 2001. *View at Google Scholar* | *View at Publisher*

[40] J. E. Booth, *Principles of textile testing*, 3rd ed. J. W. Arrowsmith Ltd: Bristol, n.d.

[41] B. P. Saville, *Physical testing of textiles*, 1st ed. England: Woodhead Publishing Ltd, 1999.

[42] M. K. Talukdar, P. K. Sriramulu, and D. B. Ajgaonkar, *Weaving*: Mahajan Publishers Pvt. Ltd, 1998.

[43] R. Marks and A. T. C. Robinson, *Principles of weaving*, 1ST ed. vol. 7: The Textile Institutes, 1976.

[44] J. E. Mcintyre and P. N. Daniels, *Textile terms and definitions*, 10th ed. Manchester: The Textile Institute, 1997.

[45] J. C. Brooks, "U.S.P. 1096283," 1914.

[46] E. H. Bollou, "U.S.P. 1721940," 1929.

[47] H. Wakefield, "B.P. 346307," 1930.

[48] P. A. B. Maxbo, "B.P. 616323," 1945.

[49] I. Patkó and L. Szabó, "The study of the flow conditions of Air jet weaving machines," presented at the 10th International Symposium of Hungarian Researchers on Computational Intelligence and Informatics, n.d.

[50] Available:http://atlas-group.gmc.globalmarket.com/products/details/atlas-copco-group-screw-air-compressor-ga75-8-5-with-large-cooler-899156.html.

[51] Available:http://www.globalmarket.com/product-info/greenair-atlas-oil-free-screw-air-compressor-zr-series-518509.html.

[52] I. Patkó, "The Nozzle's impact on the quality of fabric on the pneumatic weaving machine," *Towards Intelligent Engineering and Information Technology*, vol. 243, pp. 583-592, 2009. *View at Google Scholar | View at Publisher*

[53] S. Adanur and S. Bahtiyarov, "Analysis of air flow in single nozzle air-jet filling insertion: Corrugated channel model," *Textile Research Journal*, vol. 66, pp. 401-406, 1996. *View at Google Scholar | View at Publisher*

[54] I. Patko, "Material transport with Air Jet," *Acta Polytechnika Hungarica*, vol. 2, pp. 53-65, 2005. *View at Google Scholar*

[55] H. Akshay Bohara, "Optimization of air consumption in air-Jet Looms." Retrived: http://textilecentre.blogspot.com/2013/07/optimization-of-air-consumption-in-air.html, n.d.

[56] S. Adanur, *Hand book of weaving', Sulzer Textile Limited Switzerland.* London: CRC Press, 2001.

[57] A. Karel, K. Petr, K. Jan, J. Slavomir, K. Vaclav, and P. Jaroslav, "Relay nozzles and weaving reed," *International Journal of Mechanical Engineering and Applications*, vol. 3, pp. 13-21, 2015. *View at Publisher*

[58] J. Abdul, "Statistical model for predicting compressed air consumption on air-jet looms," *Journal of Engineered Fibers and Fabrics*, vol. 9, pp. 50-56, 2014. *View at Google Scholar*