AIR FLOW AND CONSUMPTION OF AN AIR-JET WEAVING MACHINE

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Abstract

A study of the air flow and consumption of an air-jet weaving machine weaving a particular cotton fabric has shown that more than 80% of the total air consumption of the machine occurred through the main and relay nozzles only, indicating that the energy efficiency of such a machine is largely dependent on the design and jet-timings of these nozzles. The study, which involved certain computations made with some reasonable assumptions, showed that approximately 90 kg of standard atmospheric air was required to propel/insert just 1.0 kg of 16.8-tex filling yarn across a 127-cm wide machine weaving a print-cloth construction at 500 ppm. The study also indicated that weaving a wide fabric on a wide machine would be more economical than weaving a relatively narrow-width fabric on a narrow-width machine such as used in this study.

Introduction

In air-jet weaving, the filling yarn is inserted with the help of a jet or puff of compressed air. Since the compressed air travels extremely fast, it propels the filling through the warp shed at a much faster rate than the conventional fly shuttle. The higher propulsion rate of filling yarn essentially enables a higher filling insertion rate, which directly contributes to a higher weaving speed and, hence, productivity of air-jet weaving. However, the economic advantage due to the higher productivity of the weaving system is somewhat offset by the required high energy consumption/cost of the system. Accordingly, an investigation of the ways and means to reduce air consumption in air-jet weaving is important. Although the textile machinery manufacturers and the textile manufacturing mills constantly look for the ways to minimize energy consumption/cost of their air-jet weaving machines, there is not much information available on the actual flow and consumption of air through the machines' various air channels. In this paper, an attempt has been made to display the air flow chart of a 127-cm wide, Draper X-3000 air-jet weaving machine and approximately determine the air flow/consumption through its various channels to try to identify the potential areas for improving the energy efficiency (i.e., cost per unit production) of the machine.

Since it was difficult to measure the actual air flow through each and every channel of the machine, a theoretical method of approximating the air flow through a nozzle of known specifications was used. The sum of the computed values of air flow (consumption) through all the channels was compared with the actual total air consumption registered by an on-line air-flow meter on the machine, while the latter was optimally weaving a cotton/polyester print cloth.

Methods and Materials

A Draper X-3000, 127-cm wide, air-jet weaving machine (which, incidentally, is not a very common machine now) was used to conduct a quantitative analysis of the air flow through its various distribution channels. As shown in Figure 1, the machine basically has five air channels:

1. The main nozzle
2. The four banks of relay nozzles
3. The yarn accumulation/reserve tray nozzle
4. The main auxiliary air
5. The lint-cleaner air

Each channel has its own air pressure regulator and cam- or solenoid- operated timing valve to adjust the air pressure and jet timings, respectively. The machine was set to optimally weave a 124 cm wide print cloth, 2835 ends X 2206 picks per meter, using a 16.8 tex (Ne 35), 50/50 cotton/polyester staple yarn for both warp and filling. Table 1 gives the machinery manufacturer's specifications of the machine's various air nozzles and Table 2 shows the optimum air pressures and jet timings deployed f or weaving the cloth. For a quick reference, Figure 2 shows a simple timing diagram of the various air jets. For example, as shown in the figure, the main air adjusted at 1.8 bar gauge pressure was cyclically ejected between the 105^o and the 225^o marks for a time duration of 120 degrees on the timing wheel.

An Hedland on-line air-flow meter was installed to measure the actual air flow through all the channels, while the machine was running. The actual total air consumption was compared with the sum of the computed values of air flows through all the channels.

A remote air compressor was used to feed compressed air to the weaving machine. The pressure and temperature of the supply air to the machine were about 5 bars and 17^{o}C (about 4^o less than the normal ambient temperature of 21^{o}C in the weave room), respectively. The air valves and pressure regulators were adjusted to appropriately distribute the supply air to the various channels. In other words, the air jet timings and durations of the various nozzles were appropriately set by adjusting the respective cams/solenoids. Once the machine was optimally set to weave the particular fabric style, the various air pressures and jet timings were recorded (Table 2). Incidentally, the compressed air by virtue of its rapid expansion and diffusion provides the necessary force and energy to transport the filling yarn

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(pick) across the width of the machine and perform other required functions.

Results and Conclusions

Figure 1 shows a schematic plan of the air flow and the filling yarn path of the weaving machine. Table 3 shows the computed and practical values of air flow or consumption. As seen, all of the air, except the auxiliary air and the lint-cleaner air, is used only in transporting the filling yarn. The computed values of air flow approximately add up to the total air consumption determined experimentally. The computed total air consumption of 0.809 m^3/min is reasonably close to the actual or practical value of 0.737 m^3/min, suggesting that the theoretical method used for computing the air flow through an independent air-distribution point may be useful in roughly estimating the air flow/consumption in airjet weaving.

Based on the data in Table 3, it seems that the main and relay nozzles were responsible for about 85% of the total air consumed. In fact, the relay nozzles alone were by far the biggest users of the air - about 70% of the total air consumption. Thus, the relay and main nozzles obviously are the potential research areas for air conservation to improve the energy efficiency of the machine. Specifically, the number or spacing, the air pressure, and the orifice design (size, internal texture and shape) of the relay nozzles are considered to be the critical factors to influence the air consumption. The main nozzle is the second bigest user of the compressed air and uses only about 15-18% of the total air. However, it is possible that even a slight reduction in its orifice size (of course, without appreciably slowing down the air velocity and consequently the filling propulsion rate), coupled with any possible improvement in its internal surface texture and any saving in the time duration of its jet, may reduce the air consumption without adversely affecting the weaving process/efficiency. The remaining, so-called secondary air channels for the auxiliary air, lint cleaner, and filling accumulator use much less air, compared to the relay and main nozzles. In fact, the air flow through all of these secondary channels is practically insignificant in the big picture of air consumption of the machine.

The computations of air flow/usage further show that the machine (operating at 500 picks per minute) used approximately 1.15 kg of the compressed air per minute in weaving the particular fabric style using a 16.8 tex (35/1 Ne), 50/50 cotton/polyester filling yarn. In other words, about 90 kg of standard air was required to propel 1.0 kg of the filling yarn under the practical weaving conditions. Assuming that by means of the various suggested machine modifications and weaving adjustments, it were possible to successfully operate a 183 cm wide machine at, say, 600 picks per minute without making any significant changes in the air parameters, the air requirement for propelling 1.0 kg of the same filling yarn could be reduced to about 60 kg of standard air. This suggests that based on the cost of unit fabric production a wider weaving machine weaving a wider fabric probably would be more cost effective than a relatively narrow-width machine weaving a relatively narrow fabric.

Other important factors that appear to be worthy of consideration for improving the air efficiency of the air-jet weaving are the shape and density of the reed, the quality and density of the warp yarns, and the shed size. All of these weaving factors affect the air expansion and diffusion, which, in turn, would influence the filling propulsion. It may be remarked here that the compressed air can do work efficiently only when it is allowed to diffuse and expand rapidly. Accordingly, the appropriate design of the machine as well as the proper adjustments and manipulations of the weaving factors stated previously can be critical in achieving the desired optimum air expansion for the maximum filling propulsion and insertion efficiencies.

Finally, based on the air flow analysis, it seems that the machine speed (however, within a very limited range) alone may not make a significant difference in the total air flow or the overall air consumption expressed in standard cubic meters per minute (SCMM) (not in per unit cloth production), as long as the air pressures and respective jet timings (in degrees on the machine fly wheel, and not in the actual time periods or durations) of the various air channels remain the same. In other words, if the machine speed somehow can be slightly increased without changing the various air jet pressures and timings (in degrees) and without adversely affecting the weaving performance, the air consumption per loom cycle and, hence, per unit fabric production would decrease, and vice versa. But, the total air flow per unit time (SCMM) would remain the same. However, in practice, when using significantly different yarns and weaving speeds, the air pressures and the jet time durations normally need to be readjusted to obtain sufficient energy to propel the filling.

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Notes

Southern Regional Research Center is one of the facilities of the Agricultural Research Service, U.S. Department of Agriculture.

Names of companies or commercial products are mentioned solely for the purpose of providing specific information; their mention does not imply recommendation nor endorsement by the U. S. Department of Agriculture over others not mentioned.

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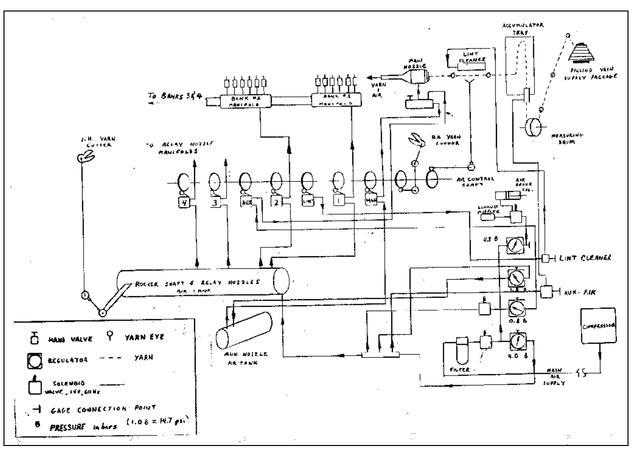

Figure 1. Air flow chart of the weaving machine.

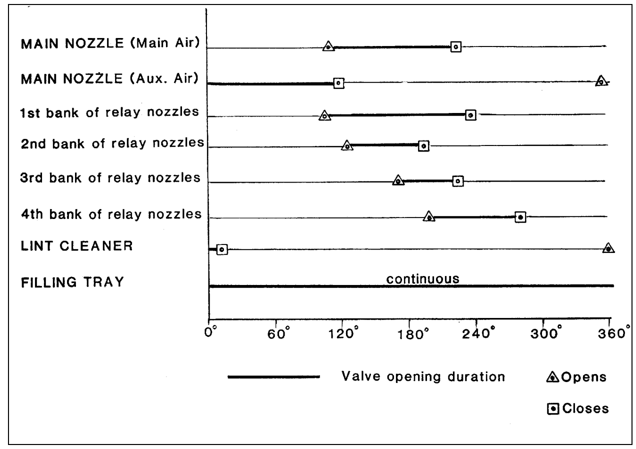

Figure 2. Timing diagram of the weaving machine.

Table 1. Specifications of the Air Nozzles

Air-Distribution Nozzles/Channels	Number of Effective Nozzles	Diameter of the Nozzle (mm)
Main air nozzle	1	4.013
Aux. air nozzle	1	4.013
Relay air nozzles:		
— First Bank	7	1.397
— Second Bank	7	1.397
— Third Bank	6	1.397
— Fourth Bank	7	1.397
Lint cleaning nozzle	1	2.032
Filling accumulator (tray air nozzle)	1	2.896

Table 2. Optimum air-pressures and jet-timings for the various air nozzles

Air Distribution Nozzles	Air Pressures (bars)		Valve Timings (deg)		Air Flow Duration (deg)
	Gauge	Absolute	Open	Close	
Main	1.8	2.8	105	225	120
Aux. Air	0.2	1.2	350	115	125
Relay					
-1st Bank	4.0	5.0	100	235	135
-2nd Bank	4.0	5.0	125	195	070
-3rd Bank	4.0	5.0	170	225	055
-4th Bank	4.0	5.0	200	280	080
Lint Cleaner	0.1	1.1	360	015	015
Filling Accumulator (tray)	0.8	1.8	continuous		360

Table 3. Quantitative analysis of air consumption of the weaving machine weaving a specific fabric style

Air Nozzle(s)	Air Velocity (m/min)	Rate of Air Flow (m^3/min)	Air Consumption	
			Computed at std. air pressure (m^3/min) (%)*	Actual Values (m^3/min) (%)*
Main nozzle (main air)	9915	0.1249	0.1165 (14.4)	0.1391 (18.9)
Main nozzle (Aux. air)	6610	0.0833	0.0641 (792)	
1st bank of relay nozzles	14780	0.0222	0.0310 (3.83/noz.)	See the total below
2nd bank of relay nozzles	14780	0.0222	0.0160 (1.98/noz.)	See the total below
3rd bank of relay nozzles	14780	0.0222	0.0125 (155/noz.)	See the total below
4th bank of relay nozzles	14780	0.0222	0.0180 (2.22/noz.)	0.5287 (7L7)
Lint cleaner	2337	0.0075	0.0005446 (0.067)	
Filling accumulator (tray) nozzle	6610	0.0436	0.097884 (12.10)	
Total Air Consumption			0.809 (100)	0.737 (100)

Total of the computed values of air consumption at standard air pressure = 0.809 m^3/min. [0.1165 + 0.641 + (7 x 0.0310) + (7 x 0.0160) + (6 x 0.0125) +(7 x 0.0180) + 0.00054 + 0.0979 m^3/min]
*Percentage of total air consumption.