New Air-jet Weft-insertion System without an Air-guide and with Double-holed Relay Nozzles: A Study of Double-holed Relay Nozzles

V. Natarajan*, V. Prasil+, F. Egrt+, and M. Hrus**

Department of Textile Technology, PSG College of Technology, Coimbatore, India
+Department of Textile Machinery, Technical University of Liberec, Liberec, Czechoslovakia
***Elitex National Corporation, Chrastava, Czechoslovakia*

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In this paper, a new air-jet weft-insertion system, which does not require any air-guide, such as a confusor or profiled reed, is discussed. Characteristics of the new double-holed relay nozzles, studied by using Pitote-tube measurement and Schlieren photography, are presented. The results of air-velocity and turbulence profiles measured by using a Laser Doppler Anemometer (LDA) are reported. The tensions developed in a stationary yarn are also studied.

Schlieren photography and Pitote-tube measurements show that, in many nozzles, the jets are either divergent or parallel with an angular lift. Measurements indicate that the air velocity near the jet axis in the weft-insertion direction is much less, with the vertical component of the air velocity accounting for more than one-third of it, and that the main nozzle imparts a higher tension to stationary yarn than the relay nozzles.

1. INTRODUCTION

Air-jet weft insertion with a profiled-reed type of air-guide has established itself as the fastest and a sufficiently versatile system of single-phase weaving technology. In spite of the lower energy consumption for the system with the confusor guide[1], the profiled reed, which is not very different from the normal reed, is more successful, since it enables one to weave any type of fabric as in any other weaving machine. The profiled tunnel of the reed helps in the separation of warp and weft during weft insertion and also facilitates the placing of relay nozzles close to the reed. Since the manufacture of a profiled reed needs precision-manufacturing technology and hence is expensive, a study has been conducted to identify the possibilities of inserting weft by means of an air-jet with a plain reed and relay nozzles[2]. This paper deals with such a method of weft insertion, in which a new type of relay nozzle is used, and discusses the characteristics of these relay nozzles.

2. THE WEFT-INSERTION MECHANISM

2.1 General Principles

Fig. 1 shows the new weft-insertion system, in which the weft is inserted across the warp shed with the help of the main nozzle (1) and relay nozzles (2) and without any air-guide or confusor. The relay nozzles used here have two nozzle holes separated by a vertical distance (Fig. 2). Weft moves between the two holes and close to the reed.

Apart from the air velocity along the axis Z, which directly influences the resultant weft-insertion velocity, the stability of the yarn along this axis decides the reliability of the weft-insertion system, since, if the yarn deviates more from this axis, then it may not be possible for it to come back again.

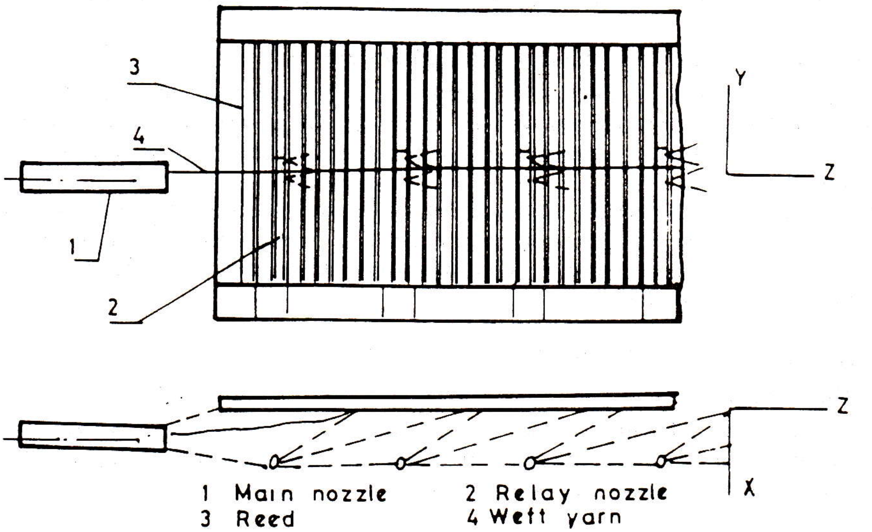


Fig. 1 Schematic diagram of the new weft-insertion system

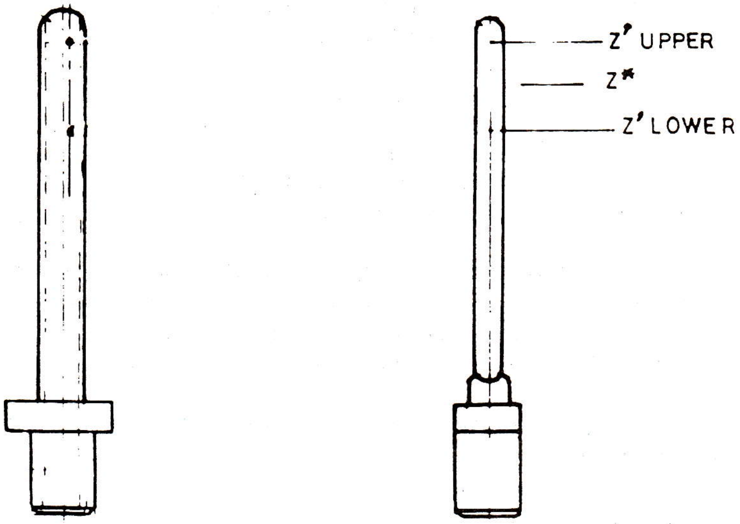


Fig. 2 New double-holed relay nozzle

2.2 Constructional Parameters

The following are the constructional parameters involved:

(*a*) the diameter of the nozzle hole, *d*, and ratio *l*/*d*, where *l* is the wall thickness of the relay nozzle;
(*b*) the parallelism of the two jets of the nozzle;
(*c*) the distance between the two holes of a nozzle; and
(*d*) the distance between adjacent nozzles.

2.3 Setting Parameters

The following setting parameters will be introduced:

(*a*) the angle of alignment of the nozzle to the reed;

(*b*) the distance between the nozzles and the reed; and
(*c*) the air pressure in individual nozzles and its variation between sections.

2.4 Influence of Constructional and Setting Parameters

The diameter and ratio *l/d* of a nozzle influence the air consumption, the reliability of weft insertion, and the distance between nozzles. Moreover, the greater the ratio *l/d*, the less will be the effect of a change or drop in air pressure on the behaviour of nozzles with respect to the jet quality[1].

The distance between adjacent nozzles, which very much influences the total air consumption and over-all economic viability of the system, depends on the parallelism of the two jets of individual nozzles, the distance between the nozzle holes, and, to a smaller extent, the diameter of the nozzle holes.

3. EXPERIMENTAL METHODS

3.1 Relay Nozzles

The relay nozzles used in the study are shown in Fig. 2. The nozzle holes have a diameter of 0.5 mm and are separated vertically by 8 mm. The ratio *l/d* equals 1.0, which is significantly higher than that for relay nozzles normally used.

3.2 Air-velocity Measurement by Means of Pitote Tube

The air velocity was measured by using a Pitote tube, whereby the total pressure was measured and the velocity was calculated from the relation:

$$v = 2 \sqrt{(P_d/\rho)} \tag{1}$$

where v = air velocity (m s^{-1}),
P_d = measured pressure (Pa), and
ρ = density of air (kg m^{-3}).

3.2 Jet-quality Assessment by Using Schlieren Photography and Pitote Tube

The other characteristic which has been studied is the quality of jets as assessed by Schlieren photography and by Pitote tube, where the total pressure at a particular point on the jet axis (20 mm from the nozzle mouth) and its inclination to the horizontal axis were measured.

3.4 Air-velocity and Turbulence Measurement by Using a Laser Doppler Anemometer (LDA)

3.4.1 Procedure for LDA Measurement

A Laser Doppler Anemometer (made by TSI in the U.S.A.), with a dual beam and back scattering, was used in the air-velocity-profile measurement. Measuring very close to the reed needs spatial and polarizing filtering of light from the Doppler signal. A Mazovia 1016 PC-XT controls the precise movement of the traversing mechanism, with the measuring device adjacent to the test rig with the reed and relay nozzles[3]. The accuracy of movement is ±0.02 mm in all the three axes. An argon laser of 500 mW with a wavelength, λ, of 514.5 mm was used for the measurement. The focusing lens had parameters of $f = 131.9$ mm and $\phi = 10.735°$.

Doppler signals were processed by a signal processor type TSI, Model 1990 B, provided with an Apple II PC. Technical parameters set on signal processor TSI 1990 B are:

filters: hi limit — 100 MHz
low limit — 2 MHz
mode: SM/B (single measurement/burst)
gain: 1
comparison %: 3% ($K = 6$ ns)

cycles/burst: 2, i.e. $N = 8$ (number of measuring cycles in Doppler signal)
$N_c = 5$ (number of cycles for comparing condition)
$r = 5/8$ (comparison ratio).

A total of 1024 sample measurements was carried out at each point of measurement. Velocity-distribution results are given by the computer in the form of histograms. Statistical parameters of the spectrum of the velocity profile are (i) mean velocity; (ii) standard deviation; and (iii) intensity of turbulence.

The mean velocity is given by:

$$v = (1/n)\,\Sigma v_i$$

where

$$v_i = \{(\lambda/2)\sin\phi\}\,N/t_N$$

where
- n = number of sample measurements at any point;
- λ = wavelength;
- ϕ = half angle of intersection;
- N = number of cycles in Doppler signal; and
- t_N = time duration for N cycles.

The standard deviation is given by:

$$\sigma = \{(1/n)\,\Sigma\,(v_i - v)^2\}^{0.5}$$

The intensity of turbulence (as a percentage) is given by:

$$T = 100\sigma/v$$

3.4.2 Test Rig for LDA Measurement

A relay-nozzle section with eight relay nozzles was used as the test rig. The air supply is from one side only through a common air chamber, where all the nozzles are fixed. A setting of 100s plain reed (20 dents/cm) was used in the experiment.

The distance between the nozzle and the plain reed was 8 mm and that between nozzles was 25 mm in this study. The eight relay nozzles were selected to be more or less identical on the basis of Schlieren photography and Pitote-tube measurements.

Air-velocity measurements along the reed were carried out by using LDA on the weft-insertion axis. The air velocity at a number of points on an axis along the reed was first measured. Since the velocity profile of these selected quality nozzles was found to be repeating, the velocity profile between the sixth and seventh nozzles was measured extensively. Points of measurements are shown in Fig. 3. The nearest point measured was 1 mm away from the reed (because of the limitations of LDA), and the measurements were made at different points spaced at 1.5 mm from each other along the X-axis. On the Y-axis, the points were spaced at 2 mm.

3.5 Yarn-tension Measurement

The tension developed in a stationary yarn by the main and relay nozzles was measured by using a tensiometer. Measurements were made on an Elitex PN165 air-jet loom converted into the system with relay nozzles as described elsewhere[4]. The stationary yarn is tied at one end and is passed around the sensing elements of the tensiometer and through the main nozzle to the system of relay nozzles and the plain reed.

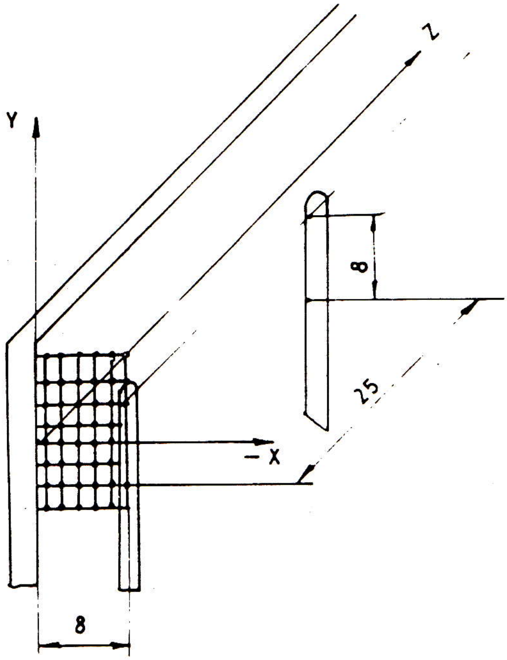


Fig. 3 Points of measurement of air velocity along the reed

4. RESULTS AND DISCUSSION

4.1 Air-velocity Measurement with a Pitote Tube

Fig. 4 shows the velocity gradient in the radial direction. The jet expansion is near-conical, and the effective jet velocity starts along the weft-insertion axis only after a distance of about 20 mm from the nozzle mouth. Fig. 5 shows the measured velocity on the axis of the air-jet at various distances from the nozzle.

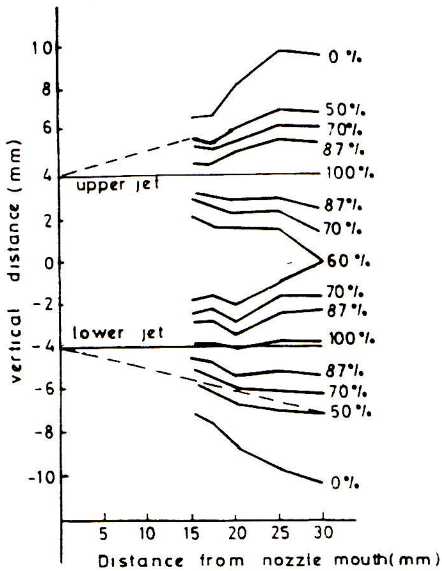


Fig. 4 Radial gradient of axial air velocity

Fig. 5 also shows the air velocity on the Z^*-axis, which is more than that at the corresponding points on the individual jet axis because of the mutual influence of two jets and also because the jet is not free and does not mix with the stationary air mass, which could have contributed to a reduction in air velocity. Air velocity increases with the distance along the designated weft-insertion axis in contrast to what occurs on the jet axis. From Fig. 5, an effective jet-active distance of about 30 mm can be considered realistic, starting at 30 mm from the nozzle mouth. Fig. 6 shows the effect of the air pressure on the air velocity on the Z^*-axis. As expected, the air velocity along the designated Z^*-axis increases proportionately with the input air pressure.

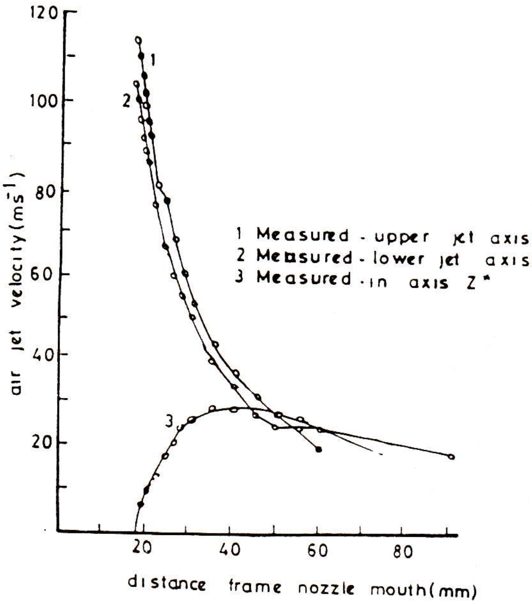


Fig. 5 Air velocity of a relay nozzle

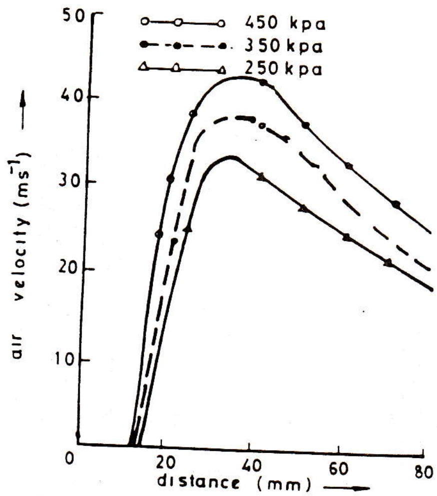


Fig. 6 Effect of air pressure on air velocity along Z^*-axis

4.2 Jet-quality Assessment by Schlieren Photography and Pitote-tube Measurement

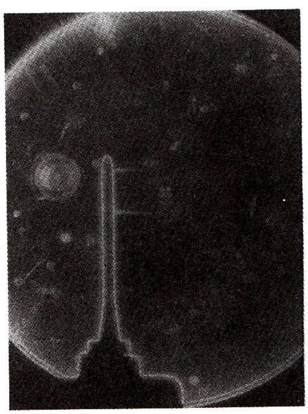
Measurements and observations showed that there are significant differences between relay nozzles due to the choking of the nozzles with dust and oil and also due to manufacturing defects. Different defects observed in the relay nozzles are:

(i) the cores of the jets of air from both the holes are shorter than normal for the same input pressure;
(ii) the core of only one of the jets from the two holes is shorter than normal for the same input pressure;
(iii) the jets are divergent;
(iv) the jest are convergent;
(v) only one of the jets is diverging;
(vi) only one of the jets is converging; and
(vii) combinations of the above.

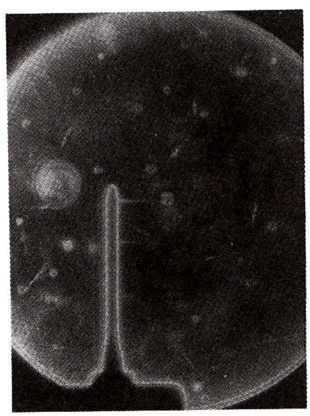
Of these, (i), (ii), (iii), and (v) are severe defects, and nozzles with any of these defects are expected to cause problems in the weft-insertion process.

When the two jets are divergent, the resultant velocity at the weft-insertion axis is expected to be less. In all, 65 relay nozzles, which were later used in the weaving trial, were subjected to these tests. Three nozzles had a jet lift of more than 3°, and twelve nozzles had a jet lift of between 2° and 3°. The total pressure measured at 20 mm from the nozzle mouth ranged from 2.84 to 7.47 kPa for an input pressure of 250 kPa. Typical Schlieren photographs of relay nozzles with equal and parallel jets and with divergent or unequal jets are shown in Fig. 7.

(*a*) A good nozzle



Divergent jets



Unequal jets

(*b*) Defective nozzles

Fig. 7 Schlieren photographs of relay nozzles

4.3 Air Velocity of Successive Relay Nozzles

4.3.1 Increase in Air Velocity

Fig. 8 shows the gradual increase in the air velocity along the weft-insertion direction, which tends to reach a maximum after a few relay nozzles. The vertical component of the air velocity near the jet axis is very high, ranging from 30 to 100% of that in the weft-insertion direction.

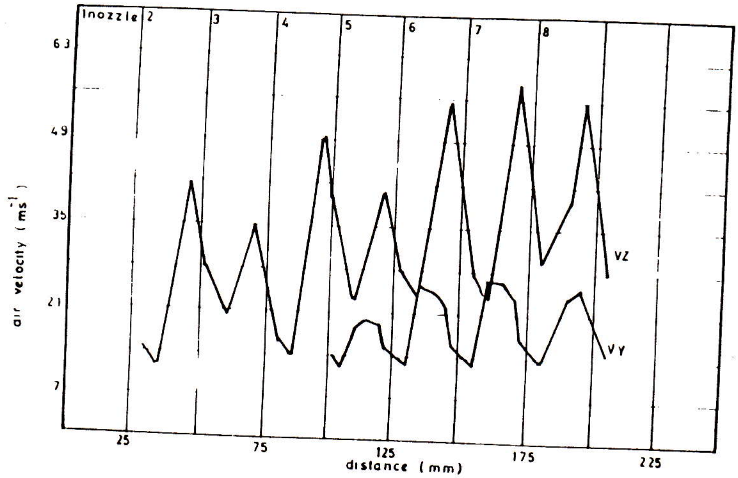


Fig. 8 Air velocity along weft-insertion and vertical axes: $X = -4$ mm, $Y = +5$ mm

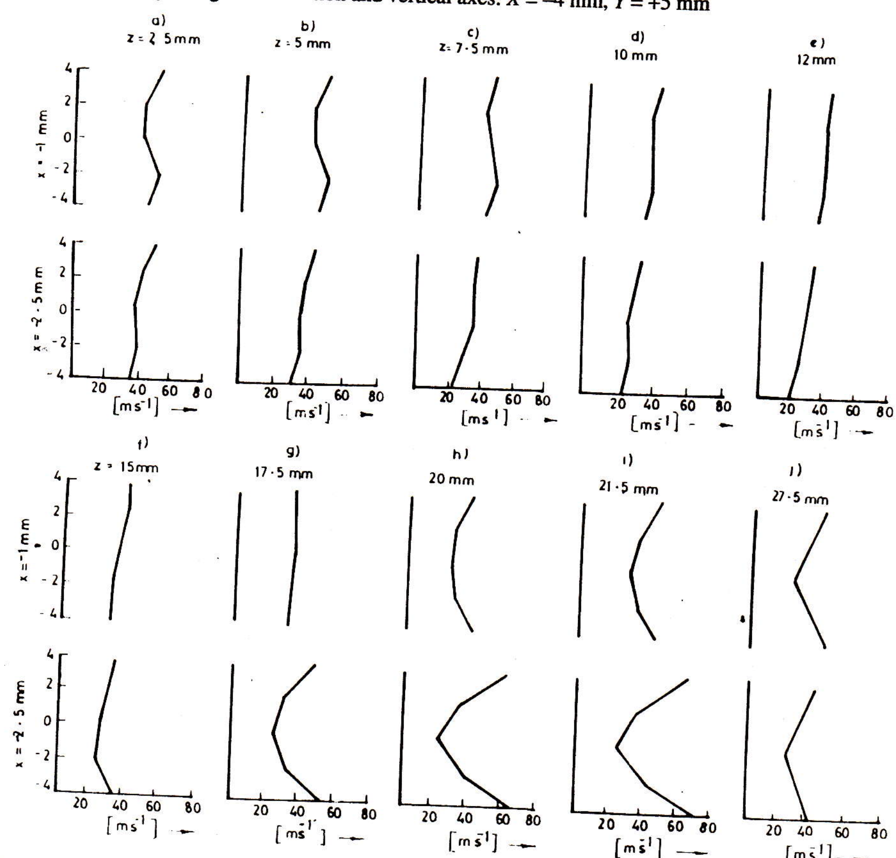


Fig. 9 Velocity profile along the reed

4.3.2 Air-velocity Profile between Two Relay Nozzles

Some results of extensive air-velocity measurements made between two relay nozzles are given in Fig. 9. Complete velocity profiles are presented in Fig. 10. As expected, the maxima of the air velocity move from the nozzle mouth to the reed, and their value decreases as the distance from the nozzle mouth increases. From 0 to 10 mm, the preceding nozzle is still active, and only after 15 mm from the nozzle is the effect of the air velocity from the measured nozzle observed. The velocity on the nearest axis along the weft-insertion direction for an angle of nozzle alignment of 15° ranges from 26 to 43 m s^{-1} at an input pressure of 300 kPa. This shows the lower potential of this weft-insertion system compared with the confusor[5] and profiled-reed systems[1]. It can also be observed that the two distinct maxima for the upper and lower jets near the reed, which are essential for successful weft insertion, are missing from $Z = 10$ cm to $Z = 17.5$ cm.

4.3.3 Turbulence of Air-jet between Two Relay Nozzles

Turbulence profiles are shown in Fig. 11. In general, the intensity of turbulence is higher when the air velocity is less. An intensity of turbulence of up to 90% has been measured at lower air velocities. Extreme values of air velocity combined with an absence of distinct maxima for the two jets of a relay nozzle near the reed may dislocate the weft yarn from the axis of weft insertion.

4.4 Tension Imparted to a Stationary Yarn

Table I shows the results of yarn tension measured on a stationary yarn. The following observations may be made from the results.

(i) The main-nozzle air pressure has a significantly larger influence on the yarn tension than that of the relay nozzles. This difference is reduced with the increasing yarn length in the jet.

(ii) With increase in the air pressure to the relay nozzles, the yarn tension increases. This improvement in tension is only marginal when the main-nozzle pressure is high.

(iii) When the main-nozzle pressure is zero, the yarn tension is greater with a relay-nozzle alignment of 15° than one of 20°. but, with a relay-nozzle alignment of 20° and high air pressure to the main and relay nozzles, the tension developed in the yarn is greater because of the higher friction between the reed and yarn and the higher air velocity along the yarn length simultaneously.

Table I
Tension Imparted to Stationary Weft by Air-jets*

Yarn Length (mm)	Relay-nozzle Pressure (kPa)	Tension (mN) Relay-nozzle Alignment = 15° Main-nozzle Pressure (kPa)				Relay-nozzle Alignment = 20° Main-nozzle Pressure (kPa)			
		0	50	100	150	0	50	100	150
225	150	2.5	11.3	24.5	35.3	2.0	12.7	28.9	39.2
	200	3.7	14.7	27.0	37.2	2.5	13.5	29.4	40.2
	250	4.4	15.7	25.5	37.2	3.2	15.2	29.9	41.2
425	150	5.4	13.2	27.9	37.2	4.9	14.5	28.9	41.2
	200	7.1	14.5	29.9	38.2	6.1	16.2	29.9	41.2
	250	7.6	16.7	32.3	39.2	7.6	17.9	30.4	42.1
625	150	7.6	15.9	29.4	40.2	6.1	15.2	28.9	42.1
	200	10.3	17.2	30.9	42.1	8.3	17.4	29.4	43.1
	250	13.5	17.2	32.3	44.1	10.5	19.1	30.4	43.1
825	150	11.8	16.0	29.4	46.1	7.4	15.4	30.9	44.1
	200	12.5	18.9	32.3	47.0	10.3	18.4	32.3	44.1
	250	14.5	21.3	34.3	48.0	12.0	20.8	32.8	45.1
1025	150	11.8	27.0	34.3	46.1	8.6	19.8	30.9	—
	200	14.2	27.9	35.3	47.0	10.5	21.1	32.8	—
	250	16.7	27.9	—	—	12.0	—	—	—

*The weft was an R32-tex/2 rotor-spun cotton yarn.

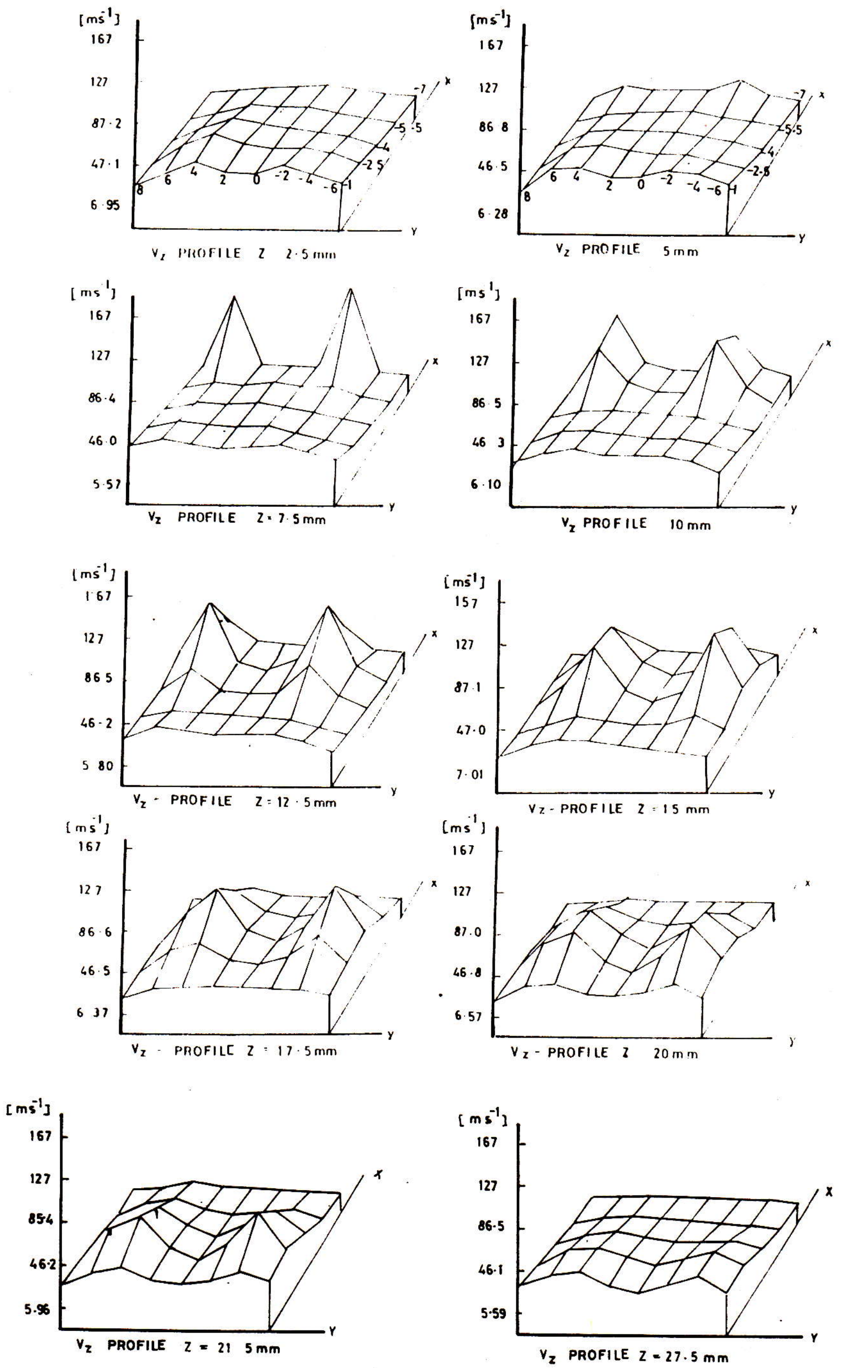


Fig. 10 Velocity profiles between two relay nozzles

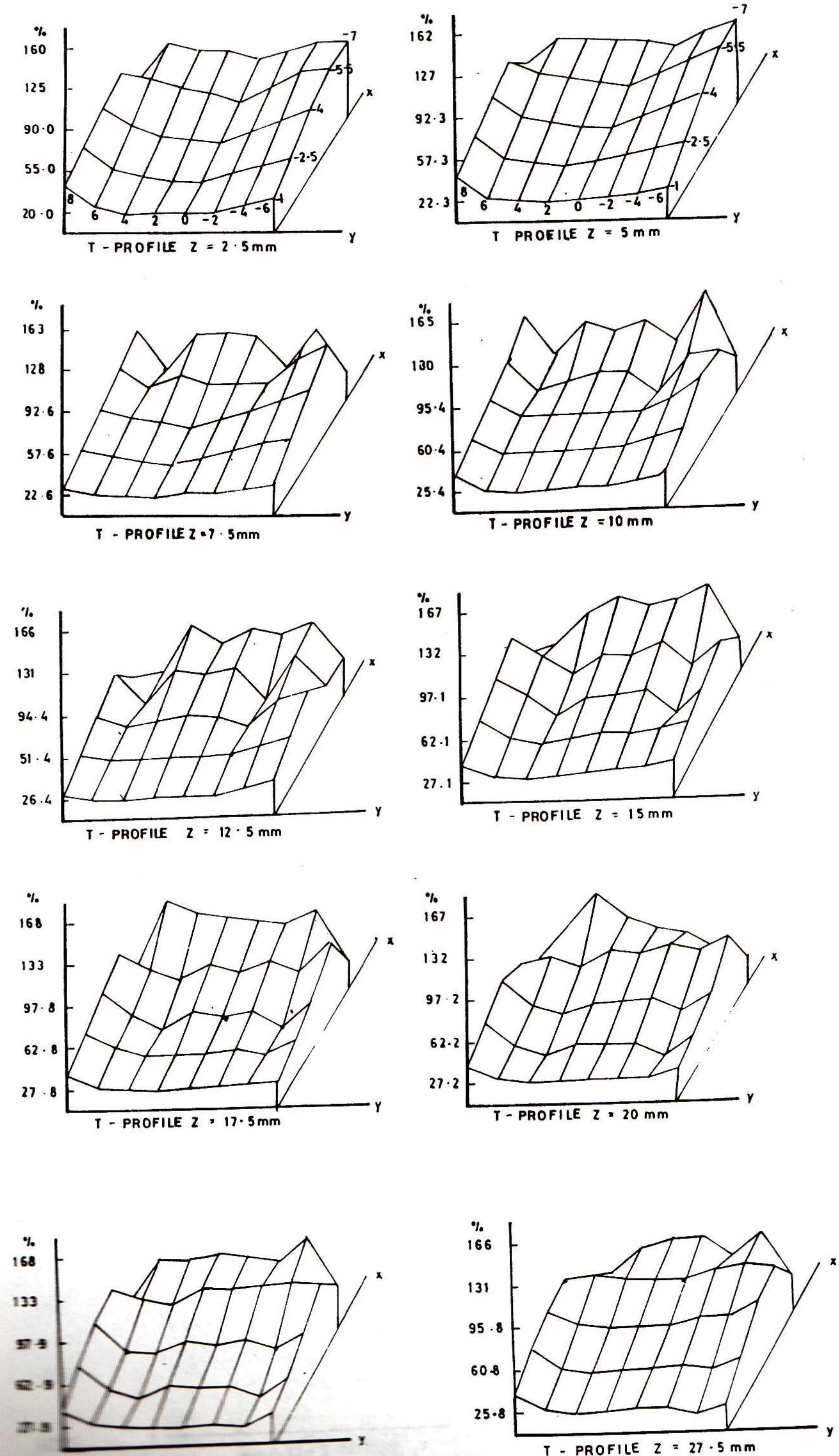


Fig. 11 Intensity of turbulence

CONCLUSIONS

[illegible] profile repeats itself along the weft-insertion axis, though there is an [illegible] for a few relay nozzles. The air velocity along the weft-insertion axis with [illegible] much less than that reported for a profiled-reed or confusor system of air-[illegible]. The vertical component of air velocity near the jet axis is more than one-[illegible] component in the weft-insertion direction.

[illegible] photographs and Pitote-tube measurements confirm the large variation in the [illegible] nozzles in terms of the variation between two holes of any nozzles and the [illegible] different nozzles. Apart from manufacturing defects, the defects are [illegible] to choking of the nozzle holes with oil and dust.

The main nozzle imparts a higher tension in a stationary yarn than the relay nozzles for [illegible] lengths. But, as the yarn length in the air-jet increases, the effect of the relay [illegible] greater.

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REFERENCES

[illegible] K. Adamek. Research Report on Weaving No. 12, Research Institute for Textile Machinery, Liberec, 1986.
[illegible] V. Natarajan. Ph.D Thesis, Technical University, Liberec, 1989.
[illegible] V. Kopecky. Research Report No.31/88, Research Institute for Textile Machinery, Liberec, 1988.
[illegible] V. Natarajan, V. Prasil, J. Mrazek, and M. Hrus. Unpublished report.
[illegible] *[illegible]rie Text.*, 1984, 552.