

Halina Dopierała,  
Czesław Radom,  
Paweł Swaczyna,  
\*Leszek Zawadzki

# Modelling of the Parameters of Air-Flow in Pneumatic Nozzles for Linking Staple and Filament Yarns. Part I. Determining of the Volume Flow and Local Speeds of Air-Flow

Textile Research Institute,  
ul. Brzezińska 5/15 92-103 Łódź, Poland  
E-mail: swaczyna@iw.lodz.pl

\*Technical University of Łódź  
Faculty of Material Technologies  
and Design of Textiles  
Department of Textile Machine Mechanics  
ul. Zeromskiego 116, 90-924 Łódź, Poland

## Abstract

*This article presents the results of different solutions of pneumatic nozzles for linking yarns manufactured from staple and filament fibres. The research focused on determining the influence of the construction design of pneumatic nozzles on forming the stream of out-flowing air. The investigations included an analysis of the construction design of interlacing nozzles with regard to their internal structure (divided into two groups depending on structural features: symmetrical and asymmetrical), an analysis of air-flow parameters, such as the local speeds of the air stream flowing out of the nozzle, measured at different points of the outlet planes of the yarn interlacing duct, the volume of air-flow, which were measured at specially prepared experimental stands, and estimation of the methods applied. The article also presents a hypothesis of air-flow in symmetrical nozzles, elaborated on the basis of experimental results.*

**Key words:** pneumatic nozzle, air-flow parameters, pneumatic linking, filament yarns.

## Introduction

The basic element in the technique and technology of the pneumatic interlacing of yarns is a pneumatic device known as an interlacing nozzle. There are many companies in the world producing such elements; however, they mainly offer nozzles recommended for linking yarns made of filament fibres. One of their characteristic parts is the interlacing duct, whose shape and dimensions are symmetrical to the inlet of air-flow. The process of linking yarns occurs in this duct as a result of a properly shaped air stream [1 - 5]. The main problem discussed in articles concerning the construction design of nozzles linking staple and filament yarns – a highly efficient technique of pneumatic linking – was determining the main parameters of air-flow: the volume flow and distribution of the speed of the air stream at different points of the outlet planes of the interlacing duct. The main factor modelling the air-flow parameters is the internal structure of the nozzle and the distribution of the air-flow parameters. These parameters decide about the possibilities of linking the components, its effect and the quality of pneumatically joined yarns.

The technological investigations on yarn interlacing using new solutions of pneumatic nozzles (described in this article) are currently being conducted, the results of which will be the subject of future articles.

For the newly developed nozzles, investigation of the parameters of air stream flowing out from both sides of the interlacing duct, its analysis and comparison of the results for nozzles with a symmetrical interlacing duct were of great importance. The results obtained, their analysis and a description of the measuring apparatus - developed and constructed at the Textile Research Institute (Instytut Włókiennictwa - IW) are presented in this article.

## Aim of the research

The aim of the investigations was to create a construction design of interlacing nozzles for the process of the pneumatic linking of staple and filament yarns, the problem of which is related to the works listed below:

- the analysis of the internal structure of interlacing nozzles offered by world companies – mainly to be used for filament yarns;
- elaboration of new construction designs of interlacing nozzles for the linking of staple yarns;
- recognition of air-flow parameters (linking medium) formed by different solutions for the construction designs of the interior of interlacing nozzles and the change in air pressure;
- elaboration of measuring methods and determination of air-flow parameters (volume flow and local speeds at the outlet planes of the nozzle).

The main problem discussed in this article is the influence of the internal construction design of the nozzles and the air-pressure on modelling the air-flow parameters – volume flow and local speeds.

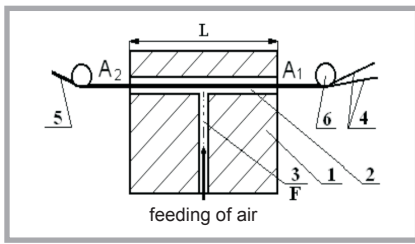
In the second part of this article we will present and discuss the average speeds of the air-flow and the asymmetry of the outflow from both sides of pneumatic nozzles of different structure.

## Analysis of the structure of pneumatic interlacing nozzles

The pneumatic interlacing nozzle is the basic element in the technique of the pneumatic interlacing of yarns [6 – 8]. It is built of an interlacing chamber (*Figure 1*) consisting of two ducts: The first one, intended for yarns to be joined, is called the yarn interlacing duct, and the second one, delivering air to the interlacing duct, is called the air duct.

The way of delivering the stream of compressed air and, at the same time, the way it acts on the yarns fed to the pneumatic linking depends on the position of the air duct in relation to the interlacing duct.

- If the air duct is located in such a way that its inlet to the interlacing duct is placed along the axis of the cross-section plane of the interlacing duct (*Figure 2.a*), which divides the duct into two equal parts (*Figure 5*); with two ducts the axis crosses this plane (*Fig-*



**Figure 1.** Scheme of a pneumatic interlacing nozzle and the process of yarn linking: 1 – Nozzle body, 2 – Yarn interlacing duct, 3 – Duct delivering air to the yarn interlacing duct, 4 – Yarns fed for interlacing, 5 – Joint (interlaced) yarn, 6 – yarn guide, F – surface of duct delivering air to the interlacing duct, A – surface of the interlacing duct: A<sub>1</sub> – inlet of yarn, A<sub>2</sub> – outlet of yarn, L – length of interlacing duct.

ure 2.b), the stream of compressed air acts on yarns in a ‘go-through’ way.

- If the air duct is located tangential to the wall of the interlacing duct (Figure 2.c), the stream of compressed air acts on the yarns in a ‘circumferential’ way.

The subject of this article is only the ‘go-through’ nozzles, characterised by a diverse internal construction design: the shape and dimensions of the yarn interlacing duct and air duct, as well as their location. The diversity of their solutions is described by the following schemes:

- different shapes of cross-sections of the yarn interlacing duct (Figure 3);
- different shapes of cross-sections of the air duct – single or double (Figure 4);
- the location of the air duct in relation to the longitudinal section of the interlacing duct – perpendicular or at a small angle (10 ÷ 15°) to the right angle (Figure 5);
- different shapes of longitudinal sections of the interlacing ducts (Figure 6).

In order to characterise the influence of the internal structure of the interlacing duct on air-flow parameters – the medi-

um linking the yarns – the nozzles were divided into two groups:

- Nozzles with a symmetrical interlacing duct, in which cross-sections are symmetrical to the air duct, and the surfaces of the outlet are the same from both sides of the interlacing duct (A<sub>1</sub> = A<sub>2</sub>); being characteristic for nozzles used for filament yarns, among which there are nozzles produced by international companies as well as by IW.

- Nozzles with an asymmetrical interlacing duct, in which cross-sections are asymmetrical to the air duct, and the surfaces of the outlet are different from both sides of the interlacing duct (A<sub>1</sub> ≠ A<sub>2</sub>). In these nozzles the interlacing duct changes:

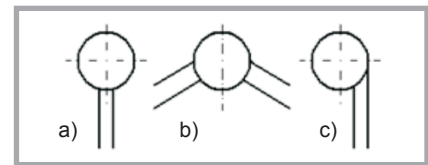
- in a convergent way (Figure 6.e) – the particular shape changes its dimensions in a convergent way;
- in a segmental way (Figure 6.f, 6.g) – the yarn interlacing duct has two segments of different dimensions, the cross-sections of which can be of the same or different shape.

The nozzles of the II group are a new solution for linking staple yarns, elaborated at the Textile Research Institute (IW), the constructions of which are the object of a patent application [9, 10].

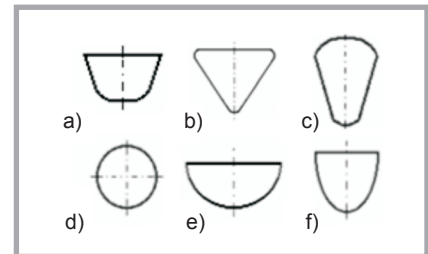
In both groups (I and II) the configuration of the air duct can be perpendicular or at a small angle to the vertical direction (according to Figure 5).

### Research material and range of the investigations

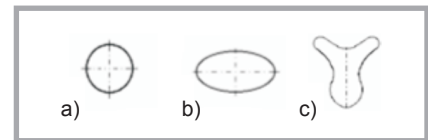
While studying the construction design of interlacing nozzles for the process of linking staple and filament yarns, investigations on different solutions of the internal structure: yarn interlacing duct – air



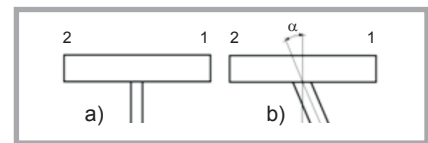
**Figure 2.** Cross-section of interlacing chambers: a and b – ‘go-through’ action, c – circumferential action.



**Figure 3.** Different shapes of the cross-section of the interlacing duct.

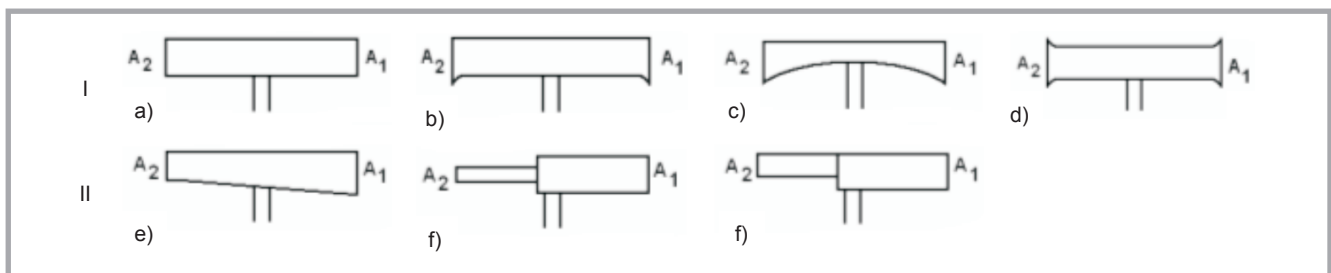


**Figure 4.** Different shapes of the cross-section of the air delivering duct.



**Figure 5.** Position of the air delivering duct in relation to the yarn interlacing duct in interlacing nozzles: a) perpendicular, b) at angle  $\alpha$ , 1, 2 – surfaces of the air outlet.

delivering duct were conducted. This is a very broad problem, which is highly problematic because of the precision of constructing the nozzle ducts required, as well as the wide range of parameter variants at small dimensions of its cross-section surfaces. The surface dimensions of different solutions of the nozzles are within the following ranges:



**Figure 6.** Different shapes of the longitudinal section of the yarn interlacing duct: I – nozzles with an interlacing duct symmetrical to the air delivering duct (A<sub>1</sub> = A<sub>2</sub>), II – nozzles with an interlacing duct asymmetrical to the air delivering duct (A<sub>1</sub> ≠ A<sub>2</sub>): e) convergent; f, g) changing in a segmental way.

**Table 1.** Exemplary variants of the nozzles of different construction designs investigated - their structure;  $U_k(x)$  position of air duct in relation to interlacing duct; where: || - perpendicular; \\\ or // - at an angle, ← direction of interlacing process.

Symbol	Longitudinal scheme, cross-sections: interlacing duct – $A_1, A_2$ , air duct – F					Structural features			
						$U_k(x)$	Surface range		
	1	2	3	4	5		6		
I. Nozzles with a symmetrical interlacing duct									
IW 02.02	$A_2$			$A_1$		1	~2.6	~2.6	
IW 02.08	$A_2$			$A_1$		1	~2.6	~2.6	
IW 03.04	$A_2$			$A_1$	\\	1	~1.3	~1.3	
06.25	$A_2$			$A_1$	\\	1	~1.3	~1.3	

- air delivering duct - 1.50 – 2.30 mm<sup>2</sup>, the value of which is constant within the length of the duct;
- yarn interlacing duct: for 'go-through' nozzles with a symmetrical duct of 1.90 – 4.90 mm<sup>2</sup>, for nozzles with an asymmetrical duct of 1.13 – 4.52 mm<sup>2</sup>; the surfaces are variable within the length of the duct, depending on the structure solution.

Table 1 presents exemplary variants of the nozzles investigated with different shapes of cross-sections of the interlacing duct. In order to determine the influ-

ence of the internal structure of the nozzles on modelling the parameters of the air stream (linking medium), the elaboration of measurement methodology was necessary.

The parameters mentioned above are:

- the value of the volume flow of air flowing through the nozzle – 'air consumption', m<sup>3</sup>/h;
- the speed of air flowing out of the pneumatic nozzle and its distribution in a cross-section of the yarn interlacing duct at the outlet planes (both sides of the interlacing duct – part II of the article).

In the next part of the article, the elaboration of methods and the preparation of a research stand is presented.

Measurements for particular nozzles were conducted, in which the air-pressure was successively changed from 0.1 to 0.40 MPa (at every 0.05 MPa), that is, with 7 values of air pressure.

## Measuring stands and methodology

### The experimental stand and methods of measuring the volume flow of air flowing through the nozzle (air-consumption)

The experimental stand to measure the volume flow of air flowing through the nozzle is built on a PY – 11 texturing machine. The scheme of the measuring stand is presented in Figure 7.

The measuring stand consists of the following elements:

- an RDN–20–R 3/4" rotameter, whose outlet is open to the environment;

- a tube equipped with a manometer to measure the air-pressure assembled at the inlet of the rotameter, which connects the rotameter to the tank, where the nozzles are installed;
- duct connecting the nozzles to the equalizing tank on the PY – 11 texturing machine; the tank is equipped with a manometer to measure the pressure of air delivered.

From the equalising tank (4), air of established pressure (Figure 7) was delivered to the nozzle investigated (3), from which it flowed to the surrounding tank (2) and next to the rotameter (1). The indications of the rotameter are given in mm (upper edge of the float). Next the volume flow (in m<sup>3</sup>/h) was read off graphs attached to the rotameter. The measurements were conducted according to standard conditions: temperature T = 293 K, air-pressure p = 0.10 MPa, and density  $\rho = 1.293$  kg/m<sup>3</sup>.

The results obtained enabled to create a graph of the dependencies of the volume flow and air-pressure), as well as to define mathematical equations to calculate the parameter for particular shapes of the nozzles. Examples of such equations for the two nozzles selected are as follows:

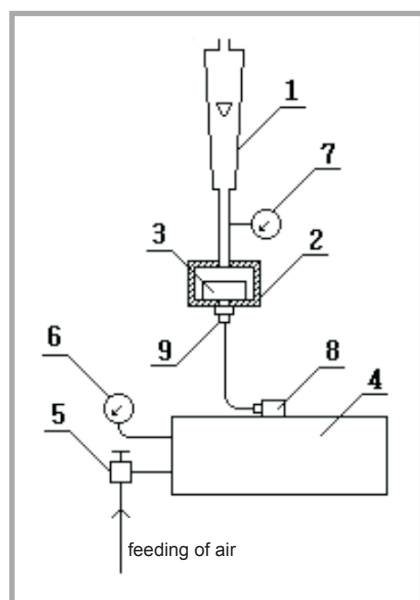
$$IW\ 03.04; Q = 0.957 \cdot p + 0.973 \quad (1)$$

$$IW\ 02.02; Q = 1.058 \cdot p + 1.021 \quad (2)$$

### The experimental stand and methods of elaborating the speed of air flowing out of the nozzle

Because of the small dimensions of the internal ducts of interlacing nozzles, it was not possible to determine the internal configuration of the air-flow. The extremely complex turbulent field of air speed made it impossible to shape the flow at bigger scales, which enabled to measure the distributions of pressure and speeds. For this reason we could only measure the speed of air flowing out from both sides of the nozzle.

The speed of air-flow was determined on the basis of dynamic air-pressure measurements, which were conducted using a Pitot microprobe (of an inlet diameter of 0.45 mm) connected to a U-tube manometer filled with mercury. The measurements of dynamic air-pressure were conducted within a range of speeds of 50 ÷ 300 m/s. The measuring probe was placed in a special holder which enabled to place it precisely, with an accuracy of



**Figure 7.** Scheme of the measuring set to determine the volume flow of air stream flowing out of the nozzle; 1 – rotameter; 2 – tank; 3 – nozzle; 4 – tank equalising the air pressure; 5 – pressure reducing valve; 6 – manometer to measure air pressure in the equalizing tank; 7 – manometer to measure air pressure before the rotameter; 8 – solenoid valve; 9 – quick release coupling.

0.1 mm, in three directions and to measure at several points right next to the outlet of the nozzle.

**Figure 8** presents the research stand used for measuring the dynamic air-pressure at the outlet and inlet of the interlacing nozzle, and **Figure 9** presents the position of the Pitot microprobe in relation to the outlet of the interlacing nozzle.

The probe inlet was at a distance of 1 mm from the outlet surface, which enabled to assume that the static air-pressure and air-pressure of the environment were equal. The number of measuring points was usually 5; however, for a few variants, because of the small cross-section surface of the yarn interlacing duct, the number of measuring points was reduced to 1. **Figure 10** presents the arrangement of measuring points depending on the cross-section of the yarn interlacing duct.

The local speeds of air-flow determined at particular measuring points (from both sides of the nozzle: inlet and outlet) are marked as:

- $V_{1.1} - V_{1.6}$  – speed of air-flow in m/s at measuring points No. 1 – 6 at the inlet of yarn,
- $V_{2.1} - V_{2.6}$  – speed of air-flow in m/s at measuring points No. 1 – 6 at the outlet of yarn.

### Determining the speed of the air stream flowing out of the nozzle

‘Go-through’ chambers are characterised by the axial outflow of air. For a speed of air below 100 m/s, this can be calculated from the dependence:

$$V = \sqrt{\frac{2p_d}{\rho}} \quad (3)$$

where:

- $V$  – speed of air-flow in m/s,
- $p_d$  – dynamic air pressure in Pa
- $\rho$  – density of air flowing out of the nozzle in kg/m<sup>3</sup>.

When measuring the dynamic air-pressure with a U-tube liquid manometer, it is possible to determine the value of the pressure on the basis of different heights of the column of liquid  $\Delta h$ :

$$p_d = \rho_{hg} \cdot g \cdot \Delta h \text{ in Pa} \quad (4)$$

where:

- $\rho_{Hg} = 13550 \text{ kg/m}^3$ ,
- $g = 9,81 \text{ m/s}^2$  – acceleration of gravity,
- $\Delta h$  – difference between the heights of the column of manometric liquid in m.

For a speed of air exceeding 100 m/s, its precise value can be calculated from the equation:

$$V = \sqrt{\frac{2\kappa}{\kappa-1} RT_{ot} \left[ 1 - \left( \frac{p_w}{p_d} \right)^{\frac{\kappa-1}{\kappa}} \right]} \quad (5)$$

where:

- $\kappa = 1.4$  – izentropic exponent for air
- $R = 287 \text{ J/kgK}$  – gas constant
- $p_w$  – air pressure of outflow from the nozzle in Pa
- $T_{ot}$  – ambient temperature in K
- $p_d$  – pressure in the tank according to monometer indications in Pa.

Measurements of the air pressure of air flowing out from both sides of the nozzle were conducted at particular points of the outlet surfaces, and then the average speeds were calculated:  $V_1$  – from the yarn inlet side, and  $V_2$  – from the yarn outlet side of the nozzle.

## Research and discussion

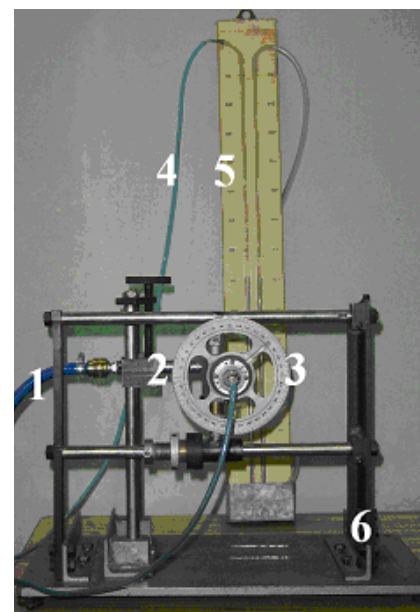
The study on the structure of pneumatic interlacing ‘go-through’ nozzles showed the complexity of factors in the modelling of the parameters of the air stream (linking medium) flowing out from a yarn interlacing duct. The analysis of the parameters selected – volume flow (Q) and local speeds (V) – showed how diverse the influence of structural parameters and air pressure is on their distribution in measuring planes from both sides of the nozzle. Generally, with an increase in air pressure, all the parameters determined increase as well.

**Volume flow** (Q, m<sup>3</sup>/h – air consumption)

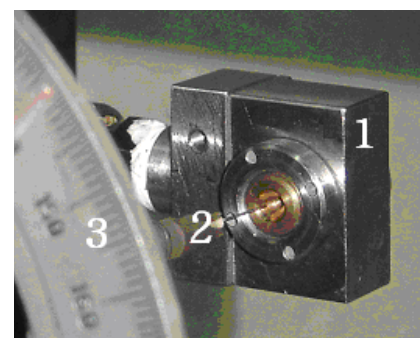
The value of the volume flow of air flowing through the nozzle (value of air consumption) mainly depends on the air pressure and the surface of the section of the duct delivering air to the yarn interlacing duct. The value of volume flow increases with an increase in the values of the parameters mentioned above. When the air pressure was changed from 0.1 to 0.50 MPa, the volume flow increased three fold, the value of which for nozzles with air duct surfaces of 1.5 – 2.3 mm<sup>2</sup> is (included) within the range:

- for 0.10 MPa 1.8 – 2.6 m<sup>3</sup>/h
- for 0.50 MPa 5.5 – 8.2 m<sup>3</sup>/h.

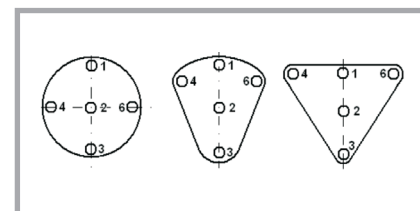
Increasing the volume flow by increasing the pressure of air fed to the nozzle increases the speed of outflow in every



**Figure 8.** Research stand to measure the speed of air-flow at the inlet and outlet of the interlacing nozzle; 1 – supply pressure conduit, 2 – port, 3 – holder of the Pitota microprobe, 4 – dynamic pressure conduit, 5 – U-tube mercury manometer, 6 – stand.



**Figure 9.** Position of the Pitot microprobe in relation to the outlet of the interlacing nozzle; 1 – interlacing nozzle investigated, 2 – Pitot microprobe, 3 – holder of Pitot microprobe.



**Figure 10.** Position of measuring points and its designations for nozzles of different shapes of the cross-section of the yarn interlacing duct.

nozzle and simultaneously decreases the asymmetry of the outflow from both sides.

### Local speeds in outflow planes

The analysis of measurements of local speeds in the outflow planes of the yarn interlacing duct showed:

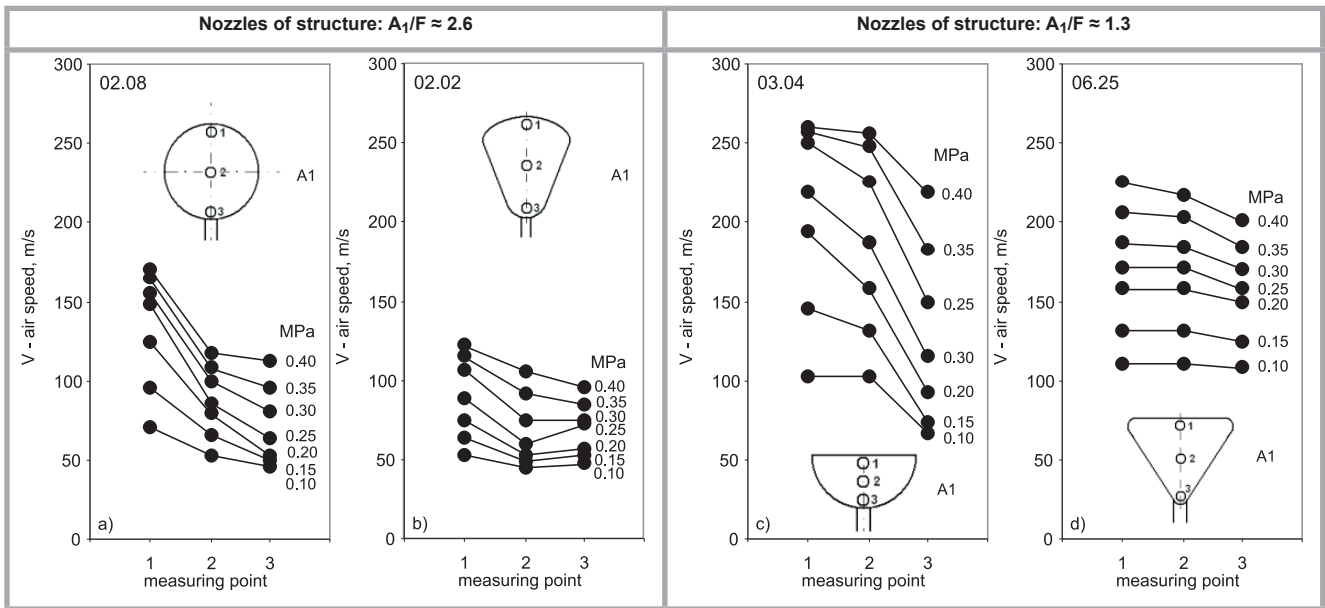


Figure 11. Distribution of local speeds of air flow at output planes of different shapes for a vertical configuration of measuring points.

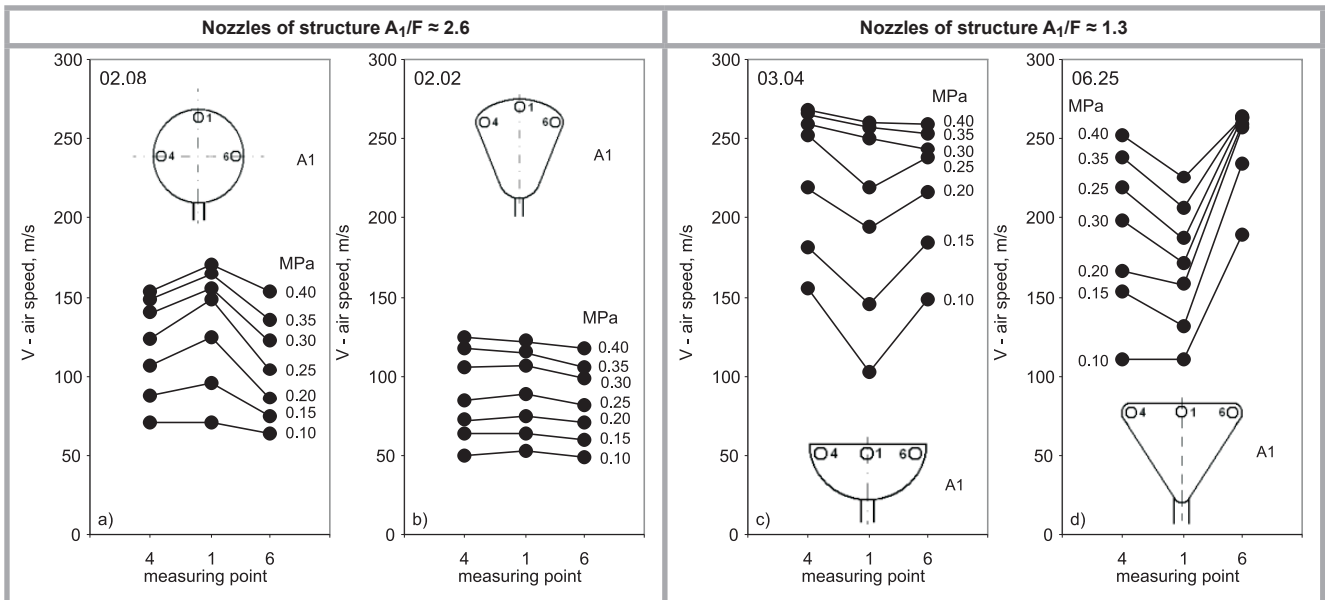


Figure 12. Distribution of local speeds of air flow at output planes of different shape for a horizontal configuration/layout of measuring points.

- differences in the speeds of air flow between measuring points in both the perpendicular (Figure 11) and horizontal configuration (Figure 12), as well as different distributions of the speed for various shapes of these surfaces,
- the highest values of air flow speed are in the upper part of the outflow surface (opposite the inlet of air), particularly in the corners and flat surfaces, whereas the smallest values are at points at the level of the outflow of air to the interlacing duct,
- a higher unevenness of the speed distribution of the air inflow are charac-

- teristic for nozzles with an interlacing duct with a pear and circular-shaped cross-section – with an arc-shaped upper surface – in relation to the ducts of a flat upper surface,
- the scatter of speeds at the outflow planes of the interlacing duct (between 5 measuring points) reached 80% for most of the nozzles investigated,
- nozzles with an internal structure determined by relation  $A/F \approx 1,3$  (surface of the interlacing duct section/ surface of the air duct section; c and d in Figures 11 and 12) have significantly higher values of the outflow speed of the air than nozzles where  $A/F \approx 2,6$

- (a and b in Figures 11 and 12) i.e. a higher value of  $A/F$ , that is, a higher difference between the section of the interlacing duct and air duct increases air decompression and decreases the speeds of its outflow at the same values of the supply pressure,
- an increase in the pressure of the air fed to the interlacing duct increases its outflow speed at each measuring point.

The analysis of the distribution and differences in the inflow speed of the air at the outflow planes of the interlacing duct enables to make a hypothesis regard-

ing the turbulent flow of the air stream through the interlacing nozzle.

### Hypothesis of air flow in the interlacing duct

Small dimensions of the interlacing duct make it impossible to measure the air-flow inside it. Thus, the determination of air flow can be only hypothetical, based on the modelling of the flow.

To establish a hypothesis of the air flow in the whole area of interlacing chambers, it should be determined whether the flow is laminar or turbulent. Therefore, the Reynolds number should be calculated using the following formula:

$$\tilde{Re} = \frac{V \cdot r_h}{\nu} \quad (6)$$

where:

$V$  – average speed of air in the inflow duct in m/s;

$r_h = A/O$  – hydraulic radius calculated for a circular-shaped section of inflow in m<sup>2</sup>;

$A$  – area of surface

$O$  – circuit in m;

$\nu$  – kinematic viscosity of the air in m<sup>2</sup>/s.

The speed of air in the air delivering duct – at the point of inflow to the interlacing duct – was measured for one particular nozzle specially prepared, for which a result of  $V = 230$  m/s was obtained, with the diameter of the inflow duct  $d = 1.5$  mm and air pressure of 0.20 MPa.

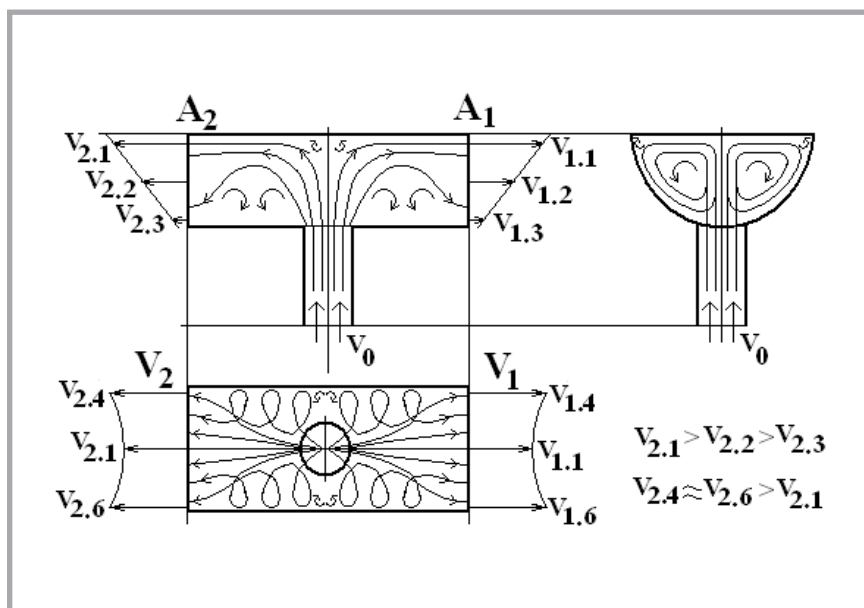
Thus, the Reynolds number is:

$$Re = 20 \cdot 10^3 > Re_{lam} = 2,3 \cdot 10^3 \quad (7)$$

The Reynolds number calculated is significantly higher than that for the laminar flow  $Re_{lam}$ , which indicates that the flow is turbulent.

A hypothetical scheme of air flow through the interlacing duct, using information obtained from the measurements of the outflow speed, is presented in **Figure 13**.

The figure presents instantaneous streamlines of the air, whose configuration in the turbulent flow is stochastically variable. Micro and macro vortexes are also illustrated here, especially in sharp corners. Some of the new construction designs of interlacing chambers have their corners rounded, which can decrease the number of micro and macro vortexes. Macro vortexes of higher kinetic energy



**Figure 13.** Hypothetical scheme of air flow in the interlacing duct;  $V_1$  and  $V_2$  – average speeds at measuring surfaces  $A_1$  and  $A_2$ .

are more advantageous for the process of interlacing yarn.

In order to create a scheme of the flow similar to the real one, a computer simulation for each interlacing chamber of different geometry is required. The image obtained depends on the correct assumptions of boundary conditions (which results from measurements of dimensions and air pressure) of the turbulence model, as well as on the density and structure of the computational network.

In recent years, instead of modelling based on the similarities of flow in models of large dimensions, modelling based on computer simulation has been introduced. Professional software, such as ANSYS CFX, FLUET and others enable to obtain an image of flow in any geometrical object. The boundary conditions and turbulence model assumed decide whether the results obtained are similar to the real existing conditions. Investigations using computer simulation will be the subject of future research works.

### Summary

1. The investigations of interlacing nozzles for high-efficiency technology of pneumatically linking staple and filament yarns yielded substantial information (indispensable for elaborating a construction design) about modelling the parameters of air flow using the internal structure of the nozzles and air pressure.

2. The internal structure of interlacing nozzles includes a system of ducts of small cross-sections. These are the yarn flow duct, where the process of interlacing yarn occurs - called the interlacing duct, and the duct delivering air to the interlacing duct. The analysis of the internal structure of the nozzles showed the diversity of their solutions with respect to the shapes of interlacing ducts (crosswise and lengthwise) and the configuration of the air duct (perpendicular or at an angle).

The nozzles investigated were divided into two groups: nozzles with a symmetrical interlacing duct (solutions of world producers and those constructed at IW) and those with an asymmetrical interlacing duct (new solutions of IW), in which the air duct is placed perpendicular or at an angle to the interlacing duct.

3. The flow parameters of the air stream were possible to determine thanks to the specially prepared measuring stands:

- The volume flow ( $Q$ ) of air flowing through the nozzle (known as air consumption – m<sup>3</sup>/h),

- Local speeds of the air stream ( $V$  – m/s) flowing out of the interlacing duct (from both sides), including the local speeds at the outflow planes, and determining the average values.

Those parameters were investigated, in which the pressure of the air was changed from 0.1 to 0.4 MPa.

4. The volume flow of air ( $Q$ ) depends on the air pressure ( $p$ ) and the value of the surface of the cross-section of the air delivering duct ( $F$ ). An increase in the value of  $p$  and  $F$  increases the value of  $Q$ .
5. The measurements of air speed at different points of the outflow planes showed differences in their value; the highest values of speed occur in the upper part, contrary to the inflow of air, especially in the flat corners of their surface. The smallest scatter of local speeds occurs in the shape of an arc-like upper surface. The results obtained enabled to make a hypothesis about the turbulent flow of air along the interlacing yarn.



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# INSTITUTE OF BIOPOLYMERS AND CHEMICAL FIBRES

## LABORATORY OF METROLOGY

The **Laboratory** is active in testing fibres, yarns, textiles and medical products. The usability and physico-mechanical properties of textiles and medical products are tested in accordance with European EN, International ISO and Polish PN standards.

### Tests within the accreditation procedure:

- linear density of fibres and yarns
- mass per unit area using small samples
- elasticity of yarns
- breaking force and elongation of fibres, yarns and medical products
- loop tenacity of fibres and yarns
- bending length and specific flexural rigidity of textile and medical products



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### Other tests:

- for fibres
  - diameter of fibres
  - staple length and its distribution of fibres
  - linear shrinkage of fibres
  - elasticity and initial modulus of drawn fibres
  - crimp index
- for yarn
  - yarn twist
  - contractility of multifilament yarns
- for textiles
  - mass per unit area using small samples
  - thickness
  - tenacity
- for films
  - thickness-mechanical scanning method
  - mechanical properties under static tension
- for medical products
  - determination of the compressive strength of skull bones
  - determination of breaking strength and elongation at break
  - suture retention strength of medical products
  - perforation strength and dislocation at perforation

### The Laboratory of Metrology carries out analyses for:

- research and development work
- consultancy and expertise

### Main equipment:

- Instron Tensile testing machines
- Electrical Capacitance Tester for the determination of linear density unevenness - Uster Type C
- Lanameter

### Contact:

INSTITUTE OF BIOPOLYMERS AND CHEMICAL FIBRES  
 ul. M. Skłodowskiej-Curie 19/27, 90-570 Łódź, Poland  
 Beata Palys M.Sc. Eng.  
 tel. (+48 42) 638 03 41, e-mail: metrologia@ibwch.lodz.pl