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# Air Flow in the Air-jet False-twist Spinning Chamber

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**Abstract**
*We discuss the air flow in a false-twist spinning chamber operating according to the MJS (Murata Jet Spinning) principle. The chamber under investigation is characterised by a straight inlet channel and a separated supply zone to avoid the yarn being formed coming into contact with air jets before their homogenisation (adjustment). The flow investigations have been conducted in two variants: for the chamber itself (without yarn) and during spinning. The influence of the yarn being formed on some selected air flow parameters in the spinning chamber has been presented as well.*

**Key words:** *air-jet spinning, false-twist chamber, air flow.*

## Introduction

The air-jet spinning method, in which the yarn is obtained from staple fibres because of the action of the swirled air jet alone, has been very attractive mainly because it has become possible to eliminate such movable elements as the spindle and the traveller in ring spinning, or the centrifuge in rotor spinning. Numerous publications in the scientific literature have been devoted to this subject; many prototype spinning frames have also been built, and some of them have been introduced into mass production and used in the textile industry.

The first industrial pneumatic spinning frame, called PF-1, was manufactured at the beginning of the 1970s in Poland in the WIFAMA Textile Machinery Factory. The yarn formation in this spinning frame was based on the open-end (OE) method with the product continuity being broken during the yarn formation, which has been discussed in detail by Golański [1]. In this solution, the diameter of the swirl chamber, conditioned by the length of fibres being processed, was equal to $d = 16$ mm. The swirled air jet that formed the yarn was generated by the suction of the air from the chamber (a sub-atmospheric pressure chamber). The yarn was characterised by a specific structure and a true twist. A schematic view of the spinning chamber in the PF-1 spinning frame is shown in Figure 1.

The spinning procedure employing this method has been also described by Jabłoński and Jackowski [11].

In [10], Dodd & Oxenham have compared the OE spinning system with the traditional ring spinning, with respect to economic profitability and future possibilities of application of both methods in production, among other aspects.

An invention by the Japanese company Murata was the next step in the progress of air-jet spinning methods. At the beginning of the 1980s, this company manufactured (and still manufactures) an air-jet spinning frame in which the yarn is formed by means of the false-twist MJS (Murata Jet Spinning) method and the product continuity is maintained during the whole spinning process. This spinning method (MJS) in comparison with the previous one (OE) has enabled what follows:

- to miniaturise the spinning chamber (the swirl chamber diameter equals 3 – 3.5 mm),
- to supply the spinning chamber with compressed air (overpressure chamber),
- to improve the yarn quality.

The yarn obtained with this method has a carrier almost without twist, which is braided on the yarn surface.

The results of investigations into this spinning method can be found, among others, in Nakahara [5] and Klein [7].

Miao, Oxenham & Grosberg in [4] describe a traditional solution, in which there are two spinning chambers arranged consecutively, which twist a stream of fibres in opposite directions. They also present a mechanism of false twist formation in air-jet spinning. Kowalczyk, Kubica & Gaca in [9] present a view of the yarn obtained with this method.

A photogram of the yarn obtained with the MJS method is depicted in Figure 2.a [9] on page 46, whereas a schematic drawing of a typical single spinning chamber is presented in Figure 2.b.

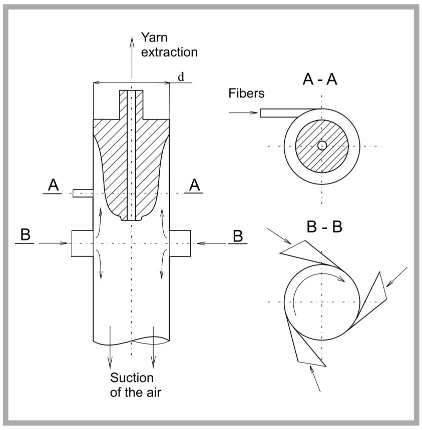


***Figure 1.*** *Schematic view of the spinning chamber in the PF 1 spinning frame [11].*

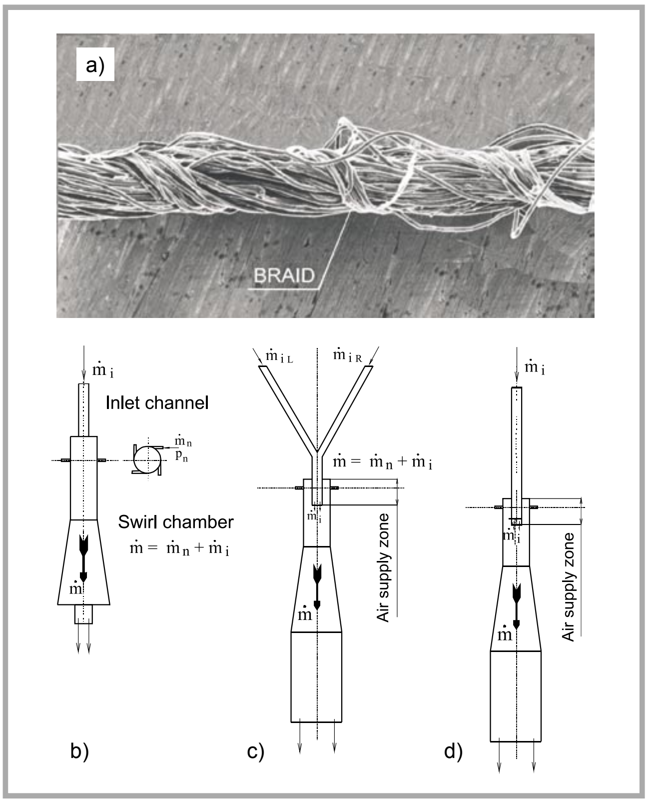


*Figure 2. a) - view of the yarn produced by the false-twist method (MJS) [9], b) – scheme of the spinning chamber in the false-twist method (MJS), c) schematic view of the Instytut Włókiennictwa - Textil Research Institute, Łódź, Poland (IW) spinning chamber with a forked inlet channel, d) schematic view of the chamber under investigation. $p_n$ – air pressure in supply nozzles, $\dot{m}_n$ – air mass flow rate supplied by supply nozzles, $\dot{m}_i$ – air mass flow rate supplied by the inlet channel, $\dot{m}$ – total air mass flow rate.*

In the late 1990s, as part of the research projects granted by the Polish State Committee for Scientific Research and entitled 'Universal, highly efficient spindleless spinning method' and 'Optimisation of technical parameters of the universal spindleless spinning method', a new original pneumatic spinn-ing method (IW) was developed at the Textile Research Institute, Łódź, under the supervision of Prof. Jóźwicki. This method combines the properties of both the methods of spinning already mentioned, namely OE and MJS. The yarn is formed in the chamber depicted in Figure 2.c. The presented version with a forked inlet channel can operate either independently or as the first chamber in the system of two chambers. The chamber is supplied with two streams of fibres, and the yarn obtains a true, one-directional twist. This way of the yarn formation is described by Jóźwicki [13], whereas the air flow in this chamber is presented by Golański and Witczak [12].

The investigations conducted by the authors as part of the above-mentioned projects have been used in the present study.

A survey of the literature shows that the investigations on air-jet spinning conducted so far have mainly been devoted to describing the chamber structures and the widely understood operation tests of the yarns obtained. The present study will describe an air flow in the chamber; this description will be the basis for the development of a computer model of the chamber and the optimisation of the spinning process parameters.

## Subject, aim and scope of the study

An over-pressure small-diameter false-twist spinning chamber, which can be treated as one of the geometrical variants of the IW method, is the subject of the present study. A schematic view of the chamber is depicted in Figure 2.d.

The chamber investigated (Figure 2.d) differs from the IW basic version (Figure 2.c) by a straight inlet channel. In comparison to other chambers of the MJS method, the version under consideration differs in the following aspects: the air supply zone is separated from the swirl chamber in order to avoid the yarn being spun coming into contact with the air jets flowing out from the supply nozzles before their homogenisation, and the compressed air supply pressure $p_n$ is higher.

The aim of the present study is to describe:
- the air flow in the chamber without yarn (before spinning), and
- the air flow in the chamber during spinning.

All the investigation results presented in this study for which the operating conditions in the chamber have not been described separately refer to the following process parameters:
- air supply pressure $p_n$ = 0.7 MPa,
- yarn delivery velocity $v_d$ = 2 m/s,
- yarn linear mass 36 tex,
- yarn made of polyester + cotton (50% PET / 50% cotton - E50B50),
- draft ratio $D$ = 0.966.

These parameters have been assumed to be optimal, and were determined on the basis of the initial operation tests.

## Air flow in the chamber without yarn

Two air jets are supplied to the swirl chamber, namely:
1) the primary air jet – swirled, affected by four tangent nozzles that are supplied with compressed air of the pressure equal to $p_n$ = 0.7 MPa and the mass flow rate $\dot{m}_n = 0.94 \cdot 10^{-3}$ kg/s,
2) the secondary air jet – introduced to the chamber by the inlet channel which is used to deliver the raw material to the chamber; generated and affected by the primary swirled air jet; the mass flow rate of the secondary air jet is $\dot{m}_i = 0.28 \cdot 10^{-3}$ kg/s.

These jets are mixed in the swirl chamber in such a way that the swirled jet of the total mass flow rate, equal to $\dot{m} = 1.22 \cdot 10^{-3}$ kg/s, flows through the swirl chamber. The outlet of the air from the chamber is free through the cylindrical part of the diameter $d_3 > d_2$.

In order to visualise the flow in the chamber, distributions of air velocity components determined in measurement planes 1 – 3, denoted on the schematic view in Figure 3.a, are presented.

The measurements of air pressures and velocities inside the spinning chamber were of necessity made without the yarn being spun. This was caused by the small diameter of the chamber ($d_2$ = 3.5 mm), which made it impossible to take direct measurements inside the chamber with a cylindrical one-hole probe. The relevant measurements were conducted in an enlarged model of the chamber (3:1) and recalculated into real conditions, employing the theory of flow similarity in swirl chambers described in [2].

In Figure 3.b, an air velocity distribution in the inlet channel $c_i$ is shown. A considerable sub-atmospheric pressure in the neighbourhood of the chamber axis causes the air jet to flow into the chamber at a significant velocity of 240 m/s. The swirl of the primary jet is not transferred to the secondary jet, and the velocity direction is consistent with the chamber axis.

In Figure 3.c, distributions of air velocity components (circumferential $c_c$ and axial $c_z$) in plane 2 are presented. The circumferential component distribution $c_c$ is typical of the forced vortex with the maximum at the wall and decreasing (approximately) linearly to the chamber axis (which is the most advantageous distribution from the viewpoint of the yarn transport). The distribution of the axial component $c_z$ indicates that a return flow of the air jet exists, which is characteristic of swirl flows, in the neighbourhood of the chamber axis. This indicates the high mixing intensity of the primary and secondary jets so that eventually there is a homogeneous, swirled jet of the mass flow rate $\dot{m}$ at the end of the cylindrical part of the diameter $d_2$. The value of the maximum resultant air velocity c at the wall is slightly higher than the sound velocity (1.06 Ma), which shows that the air in the supply nozzles reaches the sound velocity, and so the flow in this supply zone is supersonic.

In Figure 3.d, a distribution of the air velocity components (circumferential $c_c$ and axial $c_z$) in plane 3 is given. Plane 3 is situated at the beginning of the cylindrical part of the diameter $d_3$. A flow from plane 2 to plane 3 is typical of all swirl chambers, with a characteristic change in the profile and a value of the air velocity that follows from the restructuring of the enforced vortex into a free one.

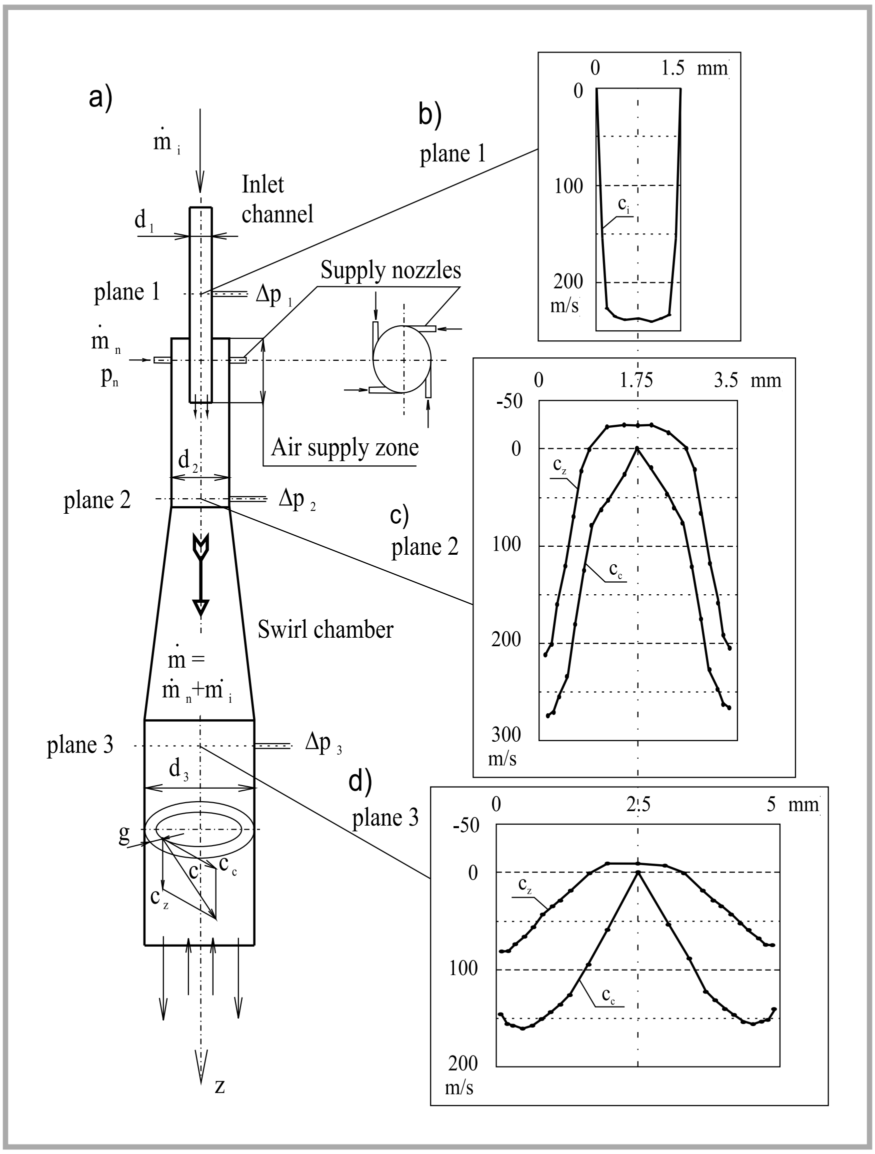


***Figure 3.*** *Schematic view of the chamber under investigation with marked measurement planes and air velocity distributions; a) schematic view of the spinning chamber; b) air velocity distribution in the inlet channel, plane 1; c) air velocity distribution in the chamber, plane 2; d) air velocity distribution in the chamber, plane 3.* ***Denotations:*** *z – axis of the spinning chamber, g – distance of the measurement point from the spinning chamber wall, plane 1, plane 2, plane 3 – measurement planes, $d_1$, $d_2$, $d_3$ – diameters of individual elements of the spinning chamber, $\Delta p_1$, $\Delta p_2$, $\Delta p_3$ – air pressure on the spinning chamber walls in measurement planes 1, 2 and 3, $p_n$ – air pressure in supply nozzles, $\dot{m}_n$ – air mass flow rate supplied by supply nozzles, $\dot{m}_i$ – air mass flow rate supplied by the inlet channel, $\dot{m}$ – total air mass flow rate, $c_c$ – circumferential component of the air velocity, $c_z$ – axial component of the air velocity, c – air velocity, $c_i$ – air velocity in the inlet channel.*

## Air flow in the chamber during spinning

During spinning, the following measurements was conducted:

- measurements and recording over time of air static pressures on the inner wall of the chamber, and
- continuous measurements of the air volume flow rate supplied into the chamber by supply nozzles.

Air static pressures on the wall were measured in the measurement of planes 1 - 3 shown in Figure 3.a, that is to say, $\Delta p_1$ in plane 1 of the inlet channel, whereas $\Delta p_2$ and $\Delta p_3$ in planes 2 and 3 of the swirl chamber, correspondingly. In order to depict an influence of the yarn on the air flow, Figure 4 (see page 48) shows the time functions of air static pressures on the wall and values of the mass flow rate $\dot{m}_n$ for the following variants:

a – without yarn,

b – during spinning.

During spinning, the mean values of the air sub-atmospheric pressure $\Delta p_1$ in the inlet channel and of the air overpressure in the swirl chamber, both $\Delta p_2$ in plane 2 and $\Delta p_3$ in plane 3, decrease. The diagrams of air pressures vs. time maintain a similar character, i.e. a time-constant value of mean pressure and similar, slight pulsations. The air mass flow rate $\dot{m}_n$ during spinning did not exhibit any significant changes during spinning. A drop in sub-atmospheric pressure in the inlet channel and in pressures on the swirl chamber wall at the unaltered mass flow rate $\dot{m}_n$ allows us to state that:

- the yarn does not affect the flow in the supply zone (where the yarn is absent);

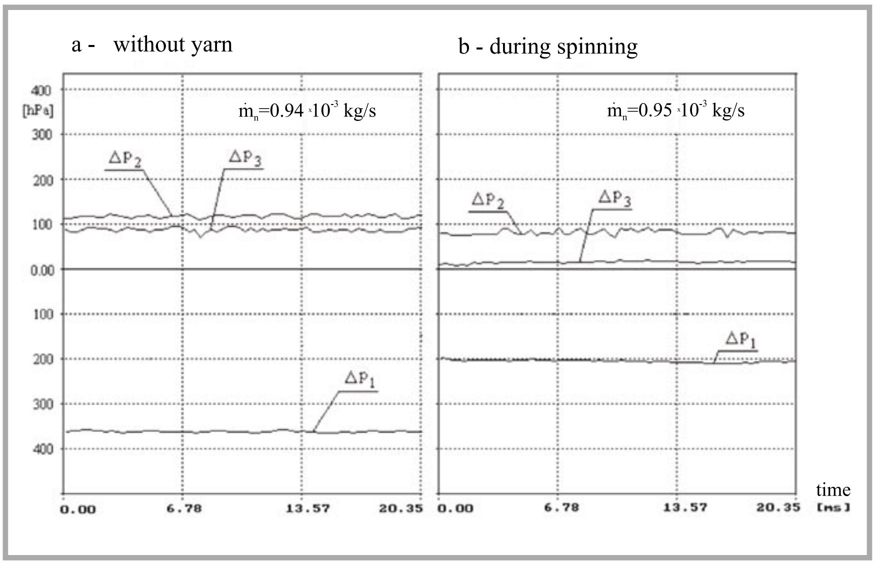


***Figure 4.** Time functions of air static pressures on the spinning chamber wall and values of the mass flow rate $\dot{m}_n$; a) without yarn, b) during spinning. $\Delta p_1$, $\Delta p_2$, $\Delta p_3$ – air pressure on the spinning chamber walls in measurement planes 1, 2 and 3, $\dot{m}_n$ – air mass flow rate supplied by supply nozzles.*

- the yarn mainly causes a decrease in the air circumferential velocity component $c_c$ in the swirl chamber;
- the decrease in the air velocity in the supply channel results from a decrease in the circumferential component in the chamber.

Based on the changes in the air sub-atmospheric pressure $\Delta p_1$, it has been estimated that a decrease in the circumferential component of the velocity $c_c$ in the chamber and a decrease in the air velocity in the inlet channel are equal to 50%.

The lack of any increase in air pressure pulsations and the fact that the time-constant values of mean values are maintained allows us to state that the yarn does not worsen the flow conditions of spinning, besides a significant change in the circumferential component of the air velocity $c_c$. While comparing the air flow in the chamber under consideration (a straight inlet, see Figure 2.d) to the flow in the variant with a forked inlet (Figure 2.c) [12], it was found that the type of air inlet did not exert any significant influence on its parameters.

## Conclusions

- The air flow in the presented spinning chamber is typical of the flow in other chambers of this spinning method.
- The yarn being spun decreases the values of pressures on the swirl chamber wall and of sub-atmospheric pressure in the inlet channel by approximately 50%, which is followed by a reduction of the value of the circumferential component of the air velocity $c_c$ in the swirl chamber and the air velocity in the inlet channel.
- From the viewpoint of yarn spinning, the flow conditions in the swirl chamber can be considered satisfactory. The initial tests have shown the usefulness of the chamber described for air-jet spinning.
- Operation tests of the chamber under consideration should be continued in further projects.

## References

1. Golański J., 'Mechanism of pneumatic formation of yarns' (in Polish); TUL Scientific Bulletin no. 235, Cieplne Maszyny Przepływowe, no. 80, Lodz 1976.
2. Kazimierski Z., Zawadzki L., 'Similarity of swirling incompressible flows in vortex tubes' (in Polish); Technical University of Łódź, Scientific Bulletin no. 235, Cieplne Maszyny Przepływowe, no. 77, Łódź 1974.
3. Grosberg P., Oxenham W., Miao M., 'Insertion of 'twist' into yarns by means of air jets. I. An experimental study of air-jet spinning. II. Twist distribution and twist insertion rates in air-jet twisting.' Journal of the Textile Institute. 1987; 78: No.3, 189-219.
4. Miao M., Oxenham W., Grosberg P., 'Yarn formation in a pneumatic system' (in Polish); Przegląd Włókienniczy 1988, pp. 360 – 364.
5. Nakahara, T., 'Air-jet Spinning Technology'. Text. Tech. Int., (1988): 73-74.
6. Miao, M., Chen, R., 'Yarn Twisting Dynamics'. Textile Research Journal, 63(3), 1993.
7. Klein, W., New Spinning Systems. The Textile Institute Manual of Textile Technology, Stephen Austin and Sons Limited, UK, 1993.
8. Oxenham, W. Basu, A., 'Effect of Jet Design on the Properties of Air-jet Spun Yarns.' Textile Res. J, 63(11), pp. 674-678 (1993).
9. Kowalczyk L., Kubica H., Gaca T., 'Influence of the spinning speed on the quality of the yarn formed with the pneumatic false-twist method' (in Polish); Przegląd Włókienniczy Łódź 1994/2.
10. Dodd E., Oxenham W., 'Open end vs. ring-spun pricing.' America's Textiles Industries. 2000; 29(9): 118-120.
11. Jabłoński W., Jackowski T., Modern spinning systems (in Polish); Bielsko-Biała 2001.
12. Golański J., Witczak D., 'Air flow and an influence of fibres and the yarn on selected parameters in the overpressure spinning chamber' (in Polish); Reports of the Textile Research Institute, vol. XLIX, Łódź 2002.
13. Jóźwicki R., 'Mechanism of formation and tensile properties of the yarn made with a new spindleless spinning method' (in Polish); Reports of the Textile Research Institute, vol. XLIX, Łódź 2002.
14. Basal G., Oxenham W., 'Vortex spun yarn vs. air-jet spun yarn'. Autex Research Journal. 2003; 3(3): 96-101.
15. Oxenham W., Spinning. Textile World. 2004; 154(1).

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