

**SIMULATION OF AIR FLOW RATE AT POINT OF CONTACT WITH A STREAM OF MELTED POLYMERIC MATERIAL**

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**Abstract:** This paper presents the research of interaction of air flow and melted material in production of fibrous materials. Correlations for calculation of air flow rate in different cross sections of a stream are acquired. The developed method of calculation of air flow rate at point of contact with stream of the melted polymeric material can be used in construction of blow heads models with a slot nozzle in production of fibrous products from different polymeric materials.

## 1 Introduction

In the technological chart of producing the thermo bonded products from polymeric fibrous materials by extrusive blowing method the most important is determination of air flow rate from slot nozzle of blow head at point of its contact with stream of the melted polymeric material flowing from exit nozzle of the melting unit.

## 2 Methods and materials used for research

Quality of the received fiber significantly depends on air flow rate at the contact point with stream of the melted material [1]. In equipment for implementation of the vertical blowing method, calculating of this rate does not present essential difficulties. For this purpose it is enough to know air outlet rate from annular nozzle of blow head and the current rate of the melted material. Required rate is defined as difference of marked rates as the directions of the considered flows match. Researches [1], [2] have proved that the average diameter of elementary fibers in production of basalt fiber by the duplex way decreases with increase of the considered rate. For one of three possible concept versions of fiber production process [1], where from single stream of the melted material of diameter  $d_c$ , the single fiber thread of diameter  $d_b$  is produced, after drawing up the equation of continuity of air flow and the melted material moving in one direction as it has been proved in research [1], formula for determination of average diameter of elementary fiber received:

$$d_b = d_c (V_c / V_{bc})^{0,5} \quad (1)$$

where  $V_c$  - the rate of flow of the melted material stream, m/s;  $V_{bc}$  - the contact rate of melted material stream with air flow from a blow head, m/s, which for the case above is defined as a difference:

$$V_{bc} = V_b - V_c \cos \gamma \quad (2)$$

where  $V_b$  - air flow rate in the merger coordinate of the melted material stream and air flow, m/s;  $\gamma$  - angle between the directions of the air flow movement and melted material stream at the merger coordinate, deg.

When producing the thermo bonded products from polymeric fibrous materials by extrusive blowing method, the directions of the air flow movement from a blow head nozzle and the melted polymeric material stream flowing from extruder exit nozzle do not match. Possible options of the given streams arrangement are presented in figure 1. All six presented options can be produced but have their special features, significant during the design process for the manufacturing of the thermo bonded products using the above method. Options (c) and (e), where air flow and the melted material stream contact under a right or acute angle, assume a vertical arrangement of extruder for melting and feed of the melted material.

Thus there is an opportunity to significantly reduce the space, occupied by the equipment, while increasing the dimensional height yielding the convenience of equipment operation. Options (a), (b), (d) and (f) assume a horizontal arrangement of extruder, where the melted material stream horizontally flows from a form-building extruder head and changes its movement direction to the vertical by gravity. The advantage of each option is in

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the fact that the operating equipment is placed horizontally, at a small height, that allows to observe and conduct the process without operator’s moving up and down.

The experimental tests of the process similar to the presented (the process of fibrous materials production from secondary polyethyleneterephthalate by vertical blowing method) indicated, that the moving rate of melted material stream is not high and measures at  $V_c = 0,05 \dots 0,2$  m/s. Air flow rate in the merger coordinate of melted material stream and air flow is significantly higher and measures at  $V_b=10\dots250$  m/s.

At such rate values, for example, for option (e) interactions of air flows and melted material stream with diameter of the melted material stream  $d_c = 0,003$  m and at angle between the directions of their movement  $\gamma =$  the 30 deg, diameter of elementary fiber determined by a formula (1) will measure at  $d_b = 0,425\dots425$  microns. Experimental tests indicated that the range of diameters of elementary fibers at various modes of technological process of their production measured at  $1\dots200$  microns. This fact confirms that from a single melted material stream single fiber is produced and it is divided into separate staple fibers by the turbulence of air flow.

The contact rate of the melted material stream and air, flowing from blow head and defining quality of the received product is mostly influenced by air flow rate at the merger coordinate with melted material stream which depends on a rate of the air, flowing from a slot-hole nozzle of a blow head, parameters of its flowing part and distance from the cut of a slot-hole nozzle to the merger coordinate of air flow and the melted material stream. For calculating of this rate you can use results of the research by G. N. Abramovich [3], [4] and other authors studying processes of flowing of the free air current from nozzle units of various design - cylindrical, slot-hole or profile channels - to the atmosphere.

Imagining the air current flowing from slot-hole nozzle of a blow head as classical free air flow [3], [4] we will notice that it has two typical parts different on flowing structure: initial and the main.

Sometimes transitional part is also allocated. In initial cross section the profile of air flow rates  $V_b = u_o$  is close to be steady. Within an initial part the core of constant rates remains. Its width linearly decreases from the size of a slot-hole nozzle in the vertical direction to zero. Outside the constant rate part, rates of the stream  $u$  naturally decrease both towards the current periphery and along the stream length. The rate profile on the initial part changes under laws of an boundary layer.

On the main part of a stream there is a decline of rate along the axis of the stream from  $V_b = u_o$  to  $V_{bm} = u_m$ . The length of an initial site  $X_u$  is defined by formula [2]:

$$X_u = 0,67 R/a \tag{3}$$

where  $R$  - the internal radius of a cylindrical nozzle in output section (we will consider previously that for a slot-hole nozzle this size is equal to a half of nozzle width),  $m$ ;  $a$  - coefficient of stream structure which for symmetric axis streams is measures at  $\approx 0,08$ .

When designing the joint of bulge of stream melted air flowing from a slot-hole nozzle of a blow head it is required to correctly appoint the adjustment range of distance from a cut of a slot-hole nozzle to a cut of an output nozzle of an extruder. Thus, for further calculation of diameter of the received elementary fiber, it is necessary to know air flow rate at the merger coordinate with the melted material stream. For this purpose it is possible to use data [3] again, however, with adjustment, which will be discussed below. The change of rate along the stream axis  $V_{bm} = u_m$  in the main site for an symmetric axis stream is determined by correlation:

$$u_m = 0,96V_o(ax/R + 0,29) \tag{4}$$

where  $x$  – the distance from a cut of a slot-hole nozzle to the required coordinate,  $m$ .

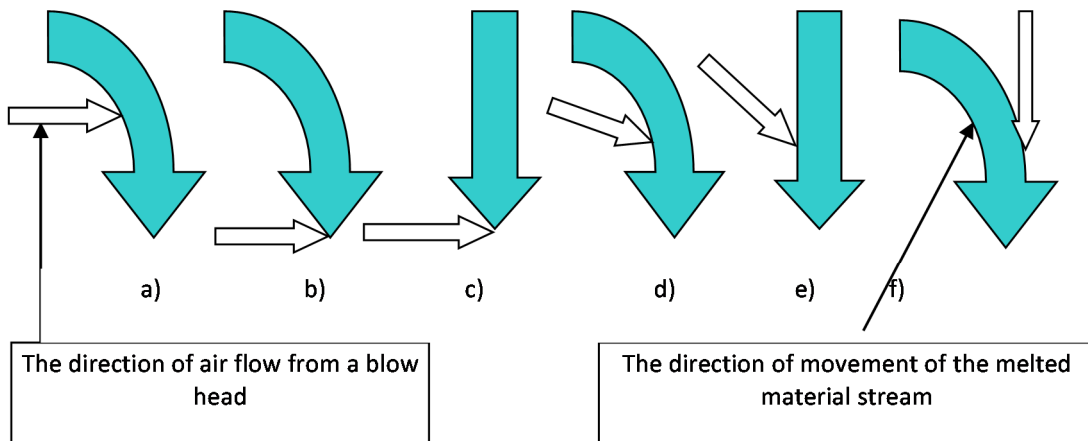


Figure 1 Options of directions of air flows and melted material interaction

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*Table 1. The parameters of a flat stream*

Cross sections	Parameters of a flat stream	Relative distance from the considered point to a stream axis					
		0	0,2	0,4	0,6	0,8	1
Transitional section	Stream rate in point $u$ , m/s	14,46	11,99	8,07	4,14	1,17	0,00
	Absolute distance from the point to a stream axis, m	0	0,008	0,016	0,024	0,032	0,04
$x=2 X_H$	Stream rate in the point $u$ , m/s	11,04	9,15	6,16	3,16	0,89	0,00
	Absolute distance from the point to a stream axis, m	0	0,014	0,028	0,042	0,056	0,07
$x=4 X_H$	Stream rate in point $u$ , m/s	8,15	6,76	4,55	2,33	0,66	0,00
	Absolute distance from the point to a stream axis, m	0	0,024	0,048	0,072	0,096	0,12

*Table 2. The parameters of a round stream*

Cross sections	Parameters of a round stream	Relative distance from the considered point to a stream axis					
		0	0,2	0,4	0,6	0,8	1
Transitional section	Stream rate in point $u$ , m/s	14,46	11,99	8,07	4,14	1,17	0,00
	Absolute distance from the point to a stream axis, m	0	0,006	0,012	0,018	0,024	0,03
$x=2 X_H$	Stream rate in the point $u$ , m/s	8,52	7,06	4,75	2,44	0,69	0,00
	Absolute distance from the point to a stream axis, m	0	0,012	0,024	0,036	0,048	0,06
$x=4 X_H$	Stream rate in the point $u$ , m/s	4,67	3,87	2,61	1,34	0,38	0,00
	Absolute distance from the point to a stream axis, m	0	0,02	0,04	0,06	0,08	0,1

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The cross profile of rate on the main part of a symmetric axis stream has the form close to the Gaussian curve. With some mistake shares which can be considered after experimental calculating of rate distribution of a stream flowing from a slot-hole nozzle, the rate  $u$  in any stream point on its main part in the vertical direction is defined by the correlation presented in the research [3]. As the rate  $u$  on the stream cross section decreases asymptotically, the stream border is established conditionally: the line, on which the rate  $u$  value is 1% of the rate on the axis  $u_m$ , is accepted for a border. If believe that the stream flowing from a slot-hole nozzle extends in the same way as the symmetric axis free stream, it enlarges in each of two cross directions under the linear law [3]:

$$\operatorname{tg}\alpha = 3,4 a \quad \operatorname{tg}\beta = 3,4 a \quad (5)$$

where  $\alpha$  и  $\beta$  – angles' halves of the extending stream in the cross directions.

Using data [3], the cross sizes of a stream  $R$  and  $H$  on the main part are defined by correlations:

$$r = (3,4ax / r_0 + 1) r_0 \quad (6)$$

$$h = (3,4ax / h_0 + 1) h_0 \quad (7)$$

where  $R_0$  and  $H_0$  - the cross sizes of a slot-hole nozzle, M.

### 3 Results and achievements

To justify the possibility of use of above correlations for calculation of air flow rate in various stream sections we will use data [5] where the comparison of results of air flow rates calculation for the specified cases is presented.

In Table 1 there are data for a flat stream, and in Table 2 - for a symmetric axis stream or round stream. Analyzing data of these tables, it is possible to draw a conclusion that up to transitional section at a distance of  $X_H$  from a nozzle cut a flat stream extends under the laws of symmetric axis one – the stream rates at different distances are identical.

At increase of distance from a cut of a round or slot-hole nozzle to  $x=2 X_H$ , the rate on a round stream axis is 8,52 m/s, and on an flat stream axis - 11,04 m/s. At further increasing of distance from a cut of a round or slot-hole nozzle to  $x=4 X_H$ , the rate on an round stream axis is 4,67 m/s, and on an flat stream axis - 8,15 m/s. Therefore the attenuation of air flow rate in a flat stream happens much more slowly, and designing the bulge joint of the melted polymer stream with the application of a blow head with a slot-hole nozzle, it allows to increase the distance from the merger coordinate of this stream with an air flow.

### Conclusions

The developed method of calculation of air flow rate in a point of its contact with a stream of the melted polymeric materials can be used when construction of blow heads models with a slot-hole nozzle for production of fibrous products from various polymeric materials.

### References

- [1] Sentyakov, B. A., Timofeev, L. V.: *The production technology of heat-insulating materials on the basis of basalt fiber*, Izhevsk: Publishing house of ISTU, p. 232, 2004.
- [2] Balog, M., Maľcovský, M.: Optimization of the production process of the plastic injection molding engineering with the technology of reverse engineering application. *Acta Tecnología*, Vol. 1, Issue 2, p. 9-12, 2015.
- [3] Abramovich, G. N.: *The theory of turbulent streams*, M: Publishing house of physical-mat. literature, p. 715, 1960.
- [4] Svyatsky, V. M., Shirobokov, K. P.: The research of influence of diffuser design data on the characteristic of fiberizer, *Messenger of ISTU*, Vol. 2010, No. 3., Izhevsk, p. 42-44, 2010.
- [5] Vikharev, A. N.: *Solution of applied tasks in hydromechanics*, Manual, Arkhangelsk: Publishing house of ASTU, p. 68, 2000.

### Review process

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