Dependences of Polypropylene Fabric Air Permeability and Flammability on the Yarn Structure and Air Pressure in a Texturing Jet

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The flammability and air permeability of woven fabric are very important properties for upholstery furniture manufacturers. In this study the dependencies of air permeability and flammability on yarn air texturing parameters, such as structure of the yarn and air pressure in the texturing jet were investigated. It was found, that air permeability depends more on yarn structure, than on air pressure in the texturing jet. Difference of air permeability of the fabrics in dependence of different structure yarns is around 17 %, when in dependence of air pressure is just 3 %. The same tendency was stated regarding fabric self extinction time. Self extinction time variation because of structure is around 19 %, and because of pressure in some cases less than 3 %. Also it was noted, that air permeability and self extinction time depends on hairiness of the yarn woven into the fabric.

Keywords: air textured yarn, woven fabrics, flammability.

1. INTRODUCTION

There are many different fabrics used for upholstery furniture. These fabrics can be produced by different technologies, from different raw materials. It can be woven, knitted, felted etc. As a raw material can be used cotton, wool, polyester, acrylic, polypropylene, and other kind of fibers or yarns can be used. In upholstery furniture it is very important to use fabrics with high quality wearing properties, such as peeling, water absorption, color fastness, shearing, flame and heat resistance, air permeability, etc. Flame and high temperature resistant fabrics and materials are desirable for use in furnishings and decorations in public accommodations and in public transit vehicles including airplanes [1]. The death toll from smoke caused by burning plastics in hotel fires or airplane crashes has drawn regulatory attention to the properties of products used in these facilities. Children's sleepwear is also a particular concern, as are items such as carpet backings [1]. Fabric flammability is affected by various factors, such as the raw material of yarn, fabric structure, oxygen concentration in the environment (moisture content, heat, air flow, etc.), and the effects of finishing the materials [2]. Important factors, which determine flammability speed and level of the different structures of textile materials, are oxygen content and its presence in construction of material. The burning process is speeded up if the air can easily penetrate through the material [3, 4]. Basically, there are three principal types of fabric properties that characterise their flammability features: 1) physical properties; 2) chemical properties; 3) thermal properties.

Physical properties include weight, structure and configuration of fabric. Chemical properties are determined by the fibers used, while the thermal properties of fabric can be defined as the textile's ability to absorb heat. Different processes to produce these fibers, make some difference in terms of behavior [5, 6, 14].

There are many studies of different authors about air permeability and flammability of the fabrics. Some works considered actual effect of the fabric properties, especially for one kind (for example, woven, knitted, nonwoven, etc.) of flame resistance. It is known that fabric weight, air permeability, and cover factor cause changes in the flame retardancy characteristics of fabrics [2].

The main structural parameters, which have influence on fabric air permeability, are set and linear densities of yarns and weave [7]. Also it is influenced by yarn twist, type of yarn structure [8] and other yarn and fibres properties.

There are many references, where main aim of the studies of air permeability of textile materials is usually to find a relationship between air permeability and structure of textiles. A textile structure is usually represented by its porosity. Pores or voids spaces could be situated in the fibres, between fibres in the threads, and between warp and weft threads in the fabrics [6].

However, there is limited experimental proof in the literature that permeability and porosity correlate. It was determined that nonwoven fabric weight is more important parameter for air permeability if to compare with thickness, fibre diameter, and density [7].

Diameter, linear density, porosity of the yarn depends on manufacturing parameters of the yarn. The goal of this paper is to show influence of yarn air texturing parameters on air permeability and flammability of the PP upholstery fabric.

2. MATERIALS AND METHODS

In order to study the influence of various structures of the yarn and such technological parameters as air pressure in the texturing jet on the properties of textured yarn and on properties of the fabric woven from these yarns, some samples of yarn were produced and some samples of fabrics weaved. Yarn samples were made from 33 tex multifilament polypropylene yarns containing 72 filaments each. The same filament yarns were used as core and effect yarns. Polypropylene was chosen due to its high

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importance for upholstery manufacturing. To produce textured yarn, an SSM RMT-D air texturing machine with a Hemajet – LB04 texturing jet was used.

Three different structure yarns were produced: 1 core yarn + 3 effect yarns (1c + 3e), 2 core yarns + 2 effect yarns (2c + 2e), 3 core yarns + 1 effect yarn (3c + 1e). 3 samples of each structure yarn were produced, changing the air pressure in the jet from 0.6 MPa to 0.7 MPa and to 0.8 MPa. When the pressure dropped below 0.6 MPa, the texturing process became impossible without changing the overfeeding and winding speed (Fig. 1 – 3).

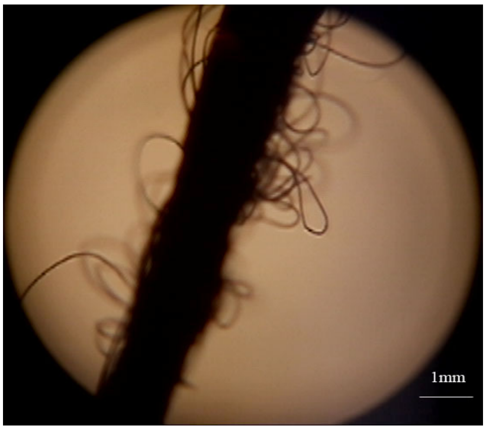

Fig. 1. Yarn structure 3c + 1e

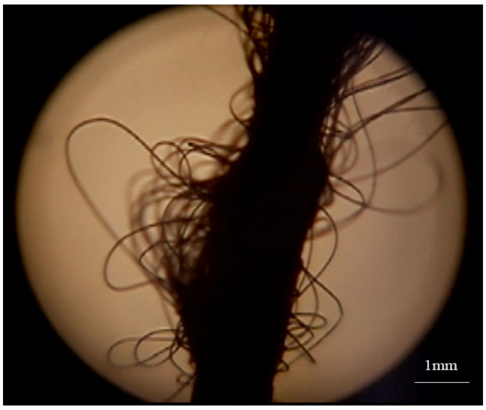

Fig. 2. Yarn structure 2c + 2e

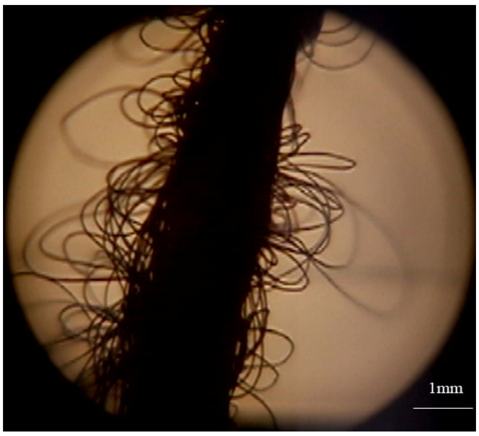

Fig. 3. Yarn structure 1c + 3e

There were no possibilities of raising the air pressure to more than 0.8 MPa because of the technical reasons. Overfeeding of core yarn was constant – 11 %. The overfeeding of the effect yarn was also constant – 43 %. The winding speed was 209.5 m/min, the same for all samples. The yarn linear density was determined using a Zweigle L 232 reeling machine and Branca Idealair Mark 160 scale. To determine the linear density of the yarn, 5 specimens of 100 m yarn length were prepared, from which an average value was taken [11]. Yarn hairiness index *H*, average protruding fibre length in 1cm of the yarn length, was measured using Uster Tester 3 yarn testing equipment (Table 1).

Table 1. Weft yarn parameters

Structure	Air pressure, MPa	Hairiness
1c + 3e	0.6	23.6
	0.7	22.4
	0.8	21.9
2c + 2e	0.6	23.4
	0.7	21.4
	0.8	20.1
3c + 1e	0.6	17.5
	0.7	15.0
	0.8	15.3

It is clear, that the properties of air-jet textured yarns are affected by air pressure, overfeed, and different over-feed levels of the core and effect components [13]. To observe the influence of texturing parameters on fabric flammability and air permeability nine samples were woven on a Somet Thema 11 rapier weaving loom. For all samples the same warp were used, but for the wefts there were yarns of three different structures: 1 core 3 effect (1c + 3e), 2core and 2 effect (2c + 2e) and 3 core and 1 effect yarn (3c+1e) produced. Each structure yarn was produced with three different air pressures: 0.6 MPa, 0.7 MPa, and 0.8 MPa in the texturing. All samples were woven under the same conditions. Set of warp was 7 cm^{-1}, set of weft was 8 cm^{-1}.

For testing of air permeability 5 specimens of each fabric, woven from different yarn, were taken. These specimens were tested on air flow meter “Karl Schroder L14DR” using pressure 0.02 MPa.

During flammability test there were also five specimens of each fabric tested. Flammability tests have been made on standard flammability test apparatus “Karl Schroder BKD” using commercial propane gas mixture. Vertical specimens were ignited by gas burner and time until self extinction was measured. Flammability was tested in weft direction.

3. RESULTS AND DISCUSSIONS

During these investigations, it was found that the variation in air permeability, caused by air pressure in air texturing jet, was less important than the variation caused by the weft yarn structure. The air permeability when air pressure is 0.6 MPa in dependence on the structure is changing from 1336 dm^3/m^2s in the case of 1c + 3e yarn, to 1450 dm^3/m^2s in the case of 2c + 2e yarn, and to

1621 dm³/m²s in the case of 3c + 1e yarn. (The relative error δ of tests does not exceed 6.5 %). The difference is around 17.5 % between air permeability of the fabrics with 3c + 1e and 1c + 3e weft yarns.

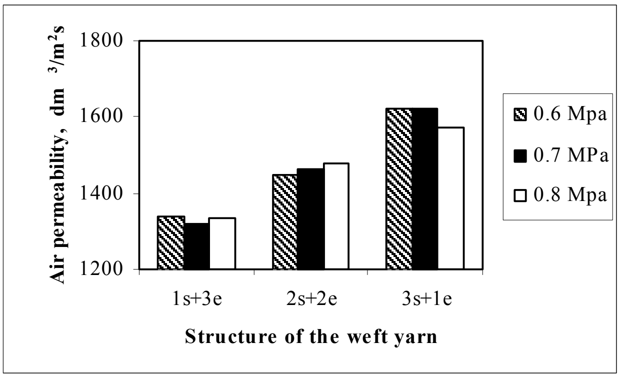

Fig. 4. Dependence of fabric air permeability on weft yarn structure

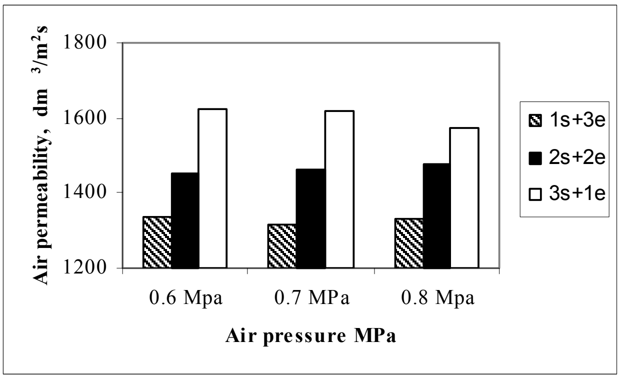

Fig. 5. Dependence of fabric air permeability on air pressure in the texturing jet

Air permeability of the fabric with weft yarn of the same structure, but produced with different pressure in the texturing jet changes by around 3 % (Figs. 4, 5) what is acceptable in upholstery furniture applications.

Interesting results were obtained during flammability tests. There is a big difference of self extinction time of fabric samples with the same structure yarn and different air pressure in the texturing jet. In case of 1c + 3e structure weft yarn produced with 0.6 MPa pressure in the jet and same structure weft yarn but produced with 0.8 MPa self extinction time difference is around 19 %, when in the case of 3c + 1e structure variation depending on air pressure is just 2.4 % and is in the limit of errors. (The relative error δ of experiment is 13.5 %). Much higher variation is caused by weft yarn structure. Self extinction time of fabrics with weft yarn produced using 0.6 MPa pressure depending on different structure is varying between 14.56 s in the case of 1c + 3e structure, 13.22 s in the case of 2c + 2e structure and 9.22 s in the case of 3c + 1e yarn structure. This gives self extinction time difference of 37 % between fabrics with 1c + 3e and 3c + 1e weft yarn. Less important variation depending on structure can be seen in case of 0.8 MPa pressure in the texturing jet. But even there it is more than 23 % (Figs. 6 and 7).

As it is well known, hairiness is one of the important parameters for spinners and for further processors [12]. During weft yarn tests there were hairiness index H of the weft yarn measured (Table1). The difference of this index in dependence of the structure of the yarn is around 30 %. This could affect air permeability and flammability properties of the fabric. It was interesting to look what relations are between hairiness of the yarn, air permeability and self extinction time of the fabric.

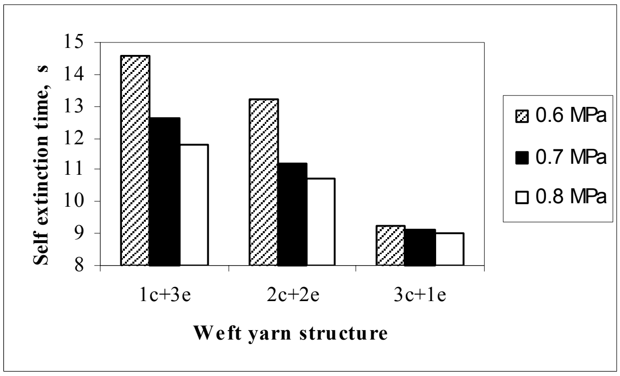

Fig. 6. Dependence of fabric self extinction time on weft yarn structure

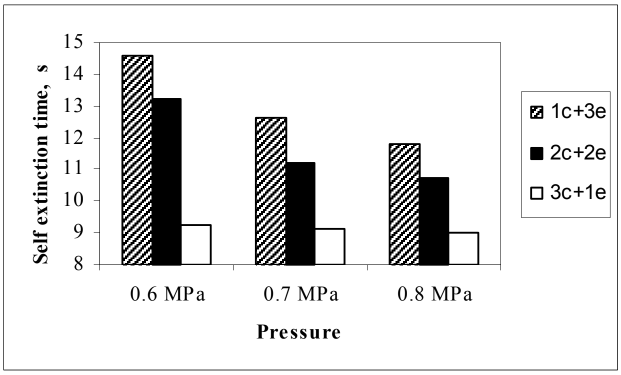

Fig. 7. Dependence of fabric self extinction time on air pressure in the texturing jet

Test results are showing that when weft yarn is more hairy, air permeability is less but the self extinction time is higher (Figs. 8 and 9).

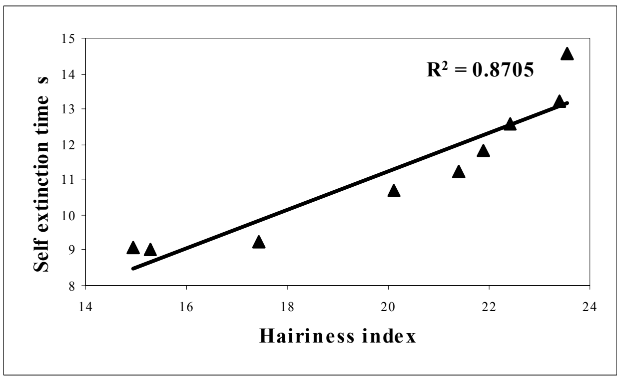

Fig. 8. Trend of self extinction time according to weft yarn hairiness

From the test results we can see strange dependence: self extinction time decreases when air permeability increases. This can be explained by the structure of textured yarns.

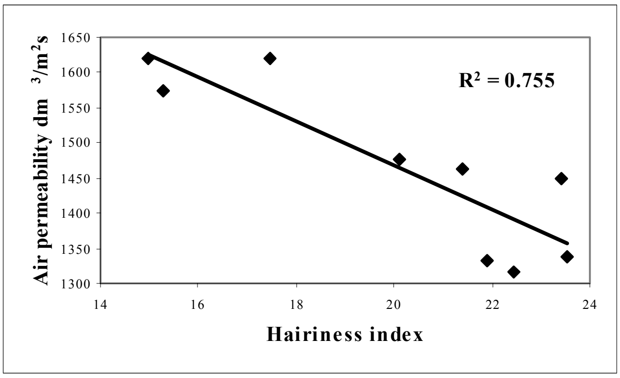

Fig. 9. Trend of self extinction time according to weft yarn hairiness

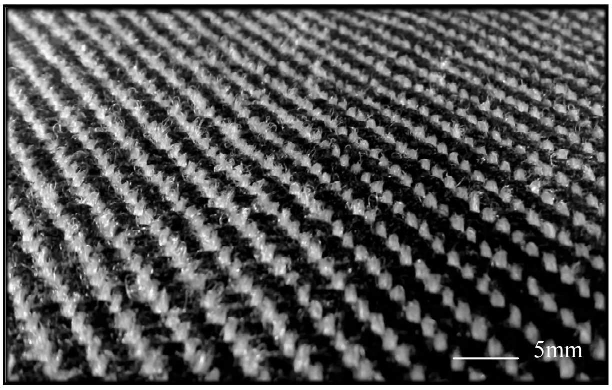

Fig. 10. Fabric with different hairiness wefts (left side yarns 1c + 3e, right side yarns 3c + 1e)

There have been fabric with most hairy (1c + 3e; 0.6 MPa) and less hairy (3c + 1e; 0.8 MPa) wefts (Fig. 10). In the left hand side of the picture we can see a part of the fabric with most hairy weft weaved. More hairy weft gives more hairy surface of the fabric. The fire is spreading more easily on the surface with protruding filament ends and loops than on clean surface, because this surface filament burning causes fire in deeper structure of the fabric.

4. CONCLUSIONS

Air permeability of the fabric depends on structure of the yarn, and does not depend on air pressure in the texturing jet.

Self extinction time of the fabric depends on both parameters, but the structure of the yarns has higher influence than air pressure in the texturing jet.

Air permeability and self extinction time of the fabric depend on hairiness of yarns. When hairiness increases, air permeability decreases, but the self extinction time decreases also.

Such controversial phenomena can be explained by higher fire catching ability of the hairy surface fabric.

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