ISSN 1392–1320 MATERIALS SCIENCE (MEDŽIAGOTYRA). Vol. 9, No. 4. 2003

Investigation of End-use Properties of Fabrics From Metaaramid Yarns

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Received 30 September 2003; accepted 21 October 2003

The investigations of end-use mechanical properties of fabrics from metaaramid yarns as well as of multilayer pocket for fireman clothes is presented in the article. The comparison of end-use properties of various metaaramid fabrics ("Nomex", "Kermel", "Conex"), which are used in the world, is presented, too. The investigation of influence of weave on end-use properties (tearing strength, air permeability, surface density) of outer fabric for fireman clothes is carried out. The regressive equations obtained has a satisfactory high determination coefficients and can be used for prognosis of properties of fabrics from "Nomex Delta TA" 18.5 tex × 2 spun yarns and obtaining of optimal weave by various requirements. The using of multilayer pocket with presented lower surface density not only decreased a cost of fireman's clothes, but also decreased a weight and increased a comfortability of clothes wearing without requirements decreasing. The designed protective fireman's clothes have been certificated in Sacsony Textile Research Institute.
Keywords: flammability of fibres, metaaramid fabrics, fireman's clothes.

1. INTRODUCTION

The use of technical textiles grow year by year and the companies of high development countries are going ever more intensively into technical textile manufacture [1, 2]. Various fabrics constitute 30 % of all technical textiles [3].

Very important property of technical textiles, especially for fire resistant clothes, is its limited oxygen index (LOI) – the percent of oxygen in environment than flame is put on. This property is very important for organic textile, which is used near a flame source – clothes for fireman, racers, pilots and etc. The fibres, which LOI is more than 23, are fire resistant in normal environment (after the elimination of the source of flame the fire extinguishes). On the other hand the LOI of paraaramid and metaaramid are the same [4, 5], but the flammability [7, 8] of fabrics from these fibres is different and depends not only on fibres nature of stock, but on fabric structure parameters (weave, linear densities and set of threads) also [9 – 12].

The most important of mechanical properties of fabrics for protective clothes against heat and fire is tearing strength, air permeability and surface density. There are many structures of fabrics, which are used for manufacture of fire resistant clothes [11 – 17]. These fabrics differ by percentage quantity of meta- and para- aramid fibres, by linear density of yarns, by sets, by surface density and etc. Herewith they are manufactured not only from various metaaramid yarns ("Nomex", "Kermel", "Conex") but also have a various weaves - each company ("Du Pont", "Akzo Nobel", "Rhone – Poulenc", "Teijin" and others) for fire resistant clothes manufacturing proposed own designed fabrics. The end-use properties of various metaaramid fabrics, which are used in the world as outer fabric of fireman's cloth, are presented in the Table 1 [13, 14].

Facts, presented in Table 1, suggest that fabrics in use differ not only by structure, but by the end-use properties, too (especially tearing strength and char length). Fireman's protective clothing according to standard EN 469 is intended to protect body, excluding the head, hands and feet, from the effects of heat and flame as well as to protect against water penetration from outside, but must be a breathable, too. The analysis of various protective clothes used in the world, show that most perspective are clothes from four layers – outer fire resistant fabric, insider breathable layer for protection against water penetration from outside, second insider layer against heat, and also fire resistant liner fabric [14 – 16].

In this article the investigations of weave influence on end-use mechanical properties of outer fabric for fire resistant clothes as well as comparable of different multilayer pockets are presented.

2. EXPERIMENTAL RESULTS AND DISCUSSIONS

2.1. Influence of weave on fabric end-use mechanical properties

One of the investigation tasks was to obtain a weave of outer fabric from particular yarns, which ensure best end-use properties. As it was stated early, the cloth end-using depends not only on fibres flammability properties, but also on some of fabric mechanical properties, which in turn depend on weave also.

During experiment the influence of weave on fabrics mechanical end-use properties was investigated. The digital weave factor P_1 (calculated by free fields of weave [17]) for weave estimation was chosen.

The six different fabrics from "Nomex Delta TA" 18.5 tex × 2 spun yarns (both in warp and in weft) were manufactured (the weave factor P_1 of each weave is presented in brackets) – plain weave (1), twill 2/1 (1.15), warp rib 2/2 (1.31), elongated twill (1.52), twill 3/3 (1.55) and basket weave 3/3 (1.81). The same set of warps (270 dm^{-1}) and the highest possible set of weft for each weave they're used. The fabrics were produced on an air-jet loom PN-170.

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Table 1. End-use properties of various metaaramid outer fabrics of fireman's cloth

Property	Nomex III twill 3/1	Nomex Delta TA twill 3/1	Kermel HTA rip-stop	Teijinconex Xfire plain
Percentage composition, %	Nomex – 95 paraaramid – 5	Nomex – 75 paraaramid – 23 carbon – 2	Kermel – 64 paraaramid – 36	Conex – 90 paraaramid – 10
Surface density, g/m^2	265	205	200	210
Tensile strength, N In warp In weft	 1440 1250	 1080 1045	 2000 2000	 1400 1200
Tearing strength, N In warp In weft	 56 60	 46 49	 200 200	 140 120
Char length, mm	10	13	5	10

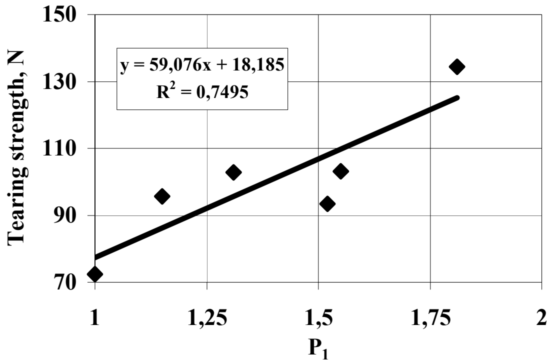

Fig. 1. Dependence of tearing strength on weave factor P_1

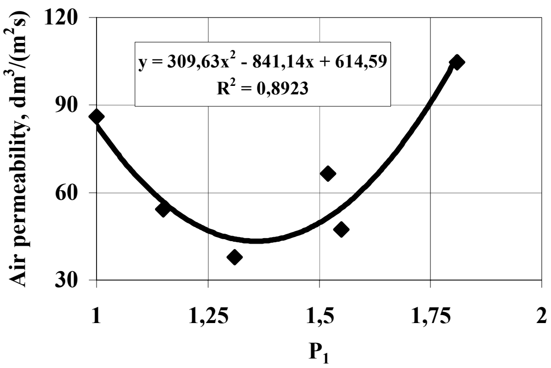

Fig. 2. Dependence of air permeability on weave factor P_1

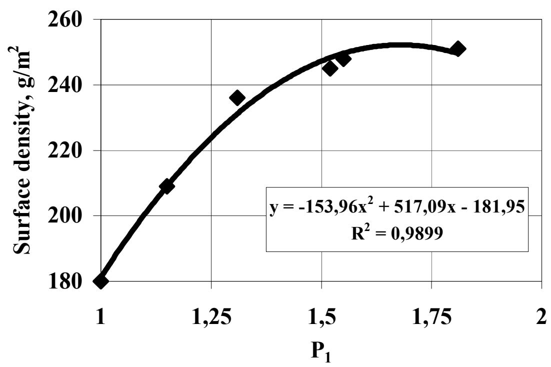

Fig. 3. Dependence of surface density on weave factor P_1

The different set of weft permits an opportunity of real fabrics obtaining, because if the set of weft for plain weave fabric and, for example, twill 3/3 were identical, the fabric of twill 3/3 weave would be unstable and useless.

The experimental investigations were done according to LST standards – LST EN ISO 13937-2, LST EN ISO 9237 (with the pressure difference of 50 Pa) and LST EN 12127. The increasing of tearing strength and decreasing of air permeability and surface density are noted positive.

The experimental results of investigations and dependences are presented in Figures 1 – 3. A lowest value of two values – tearing strength in weft and tearing strength in warp was defined as the tearing strength, because it is no account for end-use which system (weft or warp) tear down. The coefficient of variation of values of experimental points of each property tests is not higher than 4 %.

As can be seen from Figures 1 – 3, the determination coefficients are satisfactory high ($R^2 = 0.7495 \div 0.9899$). So, it is possible to state, that regressive equations obtained can be used for prognosis of properties of fabrics from "Nomex Delta TA" 18.5 tex × 2 spun yarns and obtaining optimal weave by various requirements.

2.2. Investigation of end-use properties of multilayer pocket of fabrics for fireman protective clothes

In this part of investigations the designing of two variants of multilayer pockets from "Nomex Delta TA" 18.5 tex × 2 spun yarns twill 2/1 outer fabric was carried out. The twill 2/1 weave (P_1=1.15) was chosen for the following reasons – this fabric has a satisfactory tearing strength (see Figure 1), low air permeability (see Figure 2) and herewith low surface density (see Figure 3).

All the layers were the same except the internal protective layer from heat – 170 g/m^2 nonwoven fabric was used for the first variant and 120 g/m^2 for second. Nonwoven and liner fabrics were sewn together into a liner layer for both variants.

The comparison of protective properties (according EN 469) of designed pockets for fireman's clothes is presented in Table 2.

The surface density of variant 1 was designed according to surface density of pocket widely used in the world for such application.

Table 2. Comparison of protective properties (according EN 469) of designed pockets for fireman's clothes

Property	Method of testing	Requirement according EN 469 standard	Variant 1	Variant 2
Surface density of pocket	EN 12127:19	–	610	560
Limited flame spread:				
afterflame time	EN 532	≤2 s	0	0
afterglow time		≤2 s	0	0
Heat transmission on exposure to flame:				
flaming	EN 367	no	no	no
hole formation		no	no	no
flaming or molten debris		no	no	no
index HTI_{24}		≥13 s	17.5	16.6
index HTI_{24}-HTI_{12}		≥4 s	5.0	4.0
Heat transmission on exposure to source of radiant heat:				
t_2	EN 366	≥22 s	29.0	27.0
t_2-t_1		≥6 s	9.0	8.5
index TF		≤60 %	45.0	44.2
Residual strength when exposed to radiant heat (outer fabric)	EN 366, ISO 5081	≥450 N (warp/weft)	1079/1045	1079/1045
Heat resistance:				
outer fabric	EN 469	≤5 % (warp/weft)	0 / 0	0 / 0
insider layer			–3.7 / –1.3	–3.7 / –1.3
liner layer			0 / 0	0.3 / –1.7
Tensile strength (outer fabric)	ISO 5081	≥450 N (warp/weft)	1110/1052	1110/1052
Tearing strength (outer fabric)	ISO 4674	≥25 N (warp/weft)	46 / 49	46 / 49
Surface wetting (outer fabric):				
unworn	ISO 4920	spray rating ≥4	5	5
after 5 washes			4	4
Dimensional change (after 5 washes):				
outer fabric	ISO 5077, ISO 6330	≤3 % (warp/weft)	–1.0 / –0.8	–1.0 / –0.8
insider layer			–3.0 / –0.7	–3.0 / –0.7
liner layer			–1.2 / –0.5	–1.2 / –0.5
Penetration by liquid chemicals (pocket):				
40 % Na OH	EN 368	run of index R / penetration index P >80 % / 0 % (for all chemicals)	99.7 / 0	99.7 / 0
36 % HCl			98.0 / 0	98.0 / 0
30 % H_2SO_4			97.0 / 0	97.0 / 0
white spirit			95.5 / 0	95.5 / 0

As can be seen from Table 2, all the properties of designed pocket are better or satisfy the requirements according standard EN 469. Therefore on the next step of investigation the pocket with reduced surface density was designed (for variant 2 the nonwoven fabric with lower surface density (120 g/m^2) was used). The decreasing of surface density makes clothes more comfortable (the weight of fireman's clothes decrease) and cheaper. As can be seen from Table 2, in this case also all the properties of designed pocket are better or satisfy the requirements.

3. CONCLUSIONS

The analysis of fire resistant fibres shows that the flammability of fabrics from these fibres is different and depends not only on fibres nature of stock, but on fabric structure parameters also. The end-use properties of various metaaramid fabrics, which are used in the world as outer fabric of fireman's cloth, are different, too.

The influence of weave on fabrics mechanical end-use (tearing strength, air permeability and surface density) properties was investigated. The regressive equations obtained allow to prognose values of these properties also of fabrics with others weaves of fabrics from "Nomex Delta TA" 18.5 tex × 2 spun yarns and obtaining optimal weave for various requirements.

Acknowledgments

The designed protective fireman clothes have been certificated in Sacsony Textile Research Institute and are used by Lithuanian firemen.

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