Impact Factor:	ISRA (India) = 6.317	SIS (USA) = 0.912	ICV (Poland) = 6.630
	ISI (Dubai, UAE) = 1.582	РИНЦ (Russia) = 3.939	PIF (India) = 1.940
	GIF (Australia) = 0.564	ESJI (KZ) = 9.035	IBI (India) = 4.260
	JIF = 1.500	SJIF (Morocco) = 7.184	OAJI (USA) = 0.350

SOI: 1.1/TAS DOI: 10.15863/TAS
International Scientific Journal
Theoretical & Applied Science

p-ISSN: 2308-4944 (print) e-ISSN: 2409-0085 (online)

Year: 2021 Issue: 11 Volume: 103

Published: 30.11.2021 http://T-Science.org

QR – Issue QR – Article

N. Crăciun
The National Research and Development Institute of Occupational Safety (INCDPM) - Alexandru Darabont
senior scientific researcher

EFFECTS OF THE THERMAL RISK FACTORS ON THE STATIC STRENGTH OF THE STRAP COMPONENTS

***Abstract**: Used during firefighting activities, due to level differences, personal fall protection systems are often exposed to the action of thermal risk factors existing at work. Being made mostly of textile materials, personal protective equipment against falling from a height can be damaged by the action of thermal risk factors and broken under the action of the main risk factor (fall), thus leading to serious and even fatal accidents. The lack of a test method to follow the way in which thermal risk factors act on the mechanical properties of system components could create a false impression of ensuring adequate protection in such environments. Considering that the textile elements may be in the form of a strap or rope and that the elements in the strap are more likely to be damaged, the study consisted in the exposure to fire and contact heat of different types of strap made of polyamide, polyester and polypropylene. The analysis of the results showed a significant decrease in the mechanical strength of the strap samples exposed to fire, compared to those exposed to contact heat. Thus, it can be concluded that the applied methods could be used to test the textile components of personal fall protection systems intended for use in environments where there is occasional contact with flame or contact with hot surfaces.*

***Key words**: textile, thermal risk factors, mechanical strength.*
***Language**: English*
***Citation**: Crăciun, N. (2021). Effects of the thermal risk factors on the static strength of the strap components. *ISJ Theoretical & Applied Science, 11 (103),* 976-980.
***Soi**: http://s-o-i.org/1.1/TAS-11-103-118 **Doi**: crossref https://dx.doi.org/10.15863/TAS.2021.11.103.118
***Scopus ASCC**: 2211.*

Introduction

As the working environments of firefighters are varied and depend mainly on the nature of the fire (burning of a house, factories, forests, warehouses, commercial spaces, etc.), the action of the dangerous factors existing in them affects both the user and the personal protection equipment damaging it. Often used during high-altitude firefighting operations, personal fall protection systems [1] must ensure that the health and safety of the firefighter is maintained by maintaining the protective characteristics throughout use. In other words, although the role for which they were designed is to prevent or stop the fall, the components of the system should be resistant to the risk factors existing in the working environment under conditions of foreseeable use. [2, p.76]

Being largely made of textile elements (strap and rope), during firefighting operations both the body support device (belt) and the connecting means may occasionally come into contact with the flame or various hot surfaces [3, p. 2] whose temperature can reach up to 300 ^{0}C [4, p 1669]. Considering that the elements in the strap due to their structure (thickness of about 2.5 mm) are more likely to be affected by the action of the risk factors present in the work environment, the study will focus on tracking their mechanical characteristics after exposure to the risk factors.

The mechanical characteristic followed in the study was the static resistance, because it is the one that establishes the relationships between external forces and stresses that occur inside it when a fall occurs.

As the strap elements are mainly used to make belts (complex and positioning), the determination of a static resistance value was achieved by critical analysis of the standards EN 358:2018 [5] and EN 361:2003 [6] specific to positioning belts respectively complex belts. Thus, adequate protection is considered to be provided if, when a force of 15 kN is applied for 3 minutes [5, p.10; 6, p.7], the straps do not break or become loose.

As there are currently no [7, p. 1] test methods to monitor the fire and contact heat behavior of components made of strap, degradation to these risk factors has been carried out by assimilating specific methods to other types of personal protection equipment (hereinafter abbreviated PPE) intended for use by firefighters.

1. ESTABLISHMENT OF DEGRADATION AND TEST METHODS

1.1. Degradation methods

Given the fact that most firefighting operations take place outdoors, in addition to thermal exposure and high humidity, there may be varying temperatures in the environment.

Thus, the methods of conditioning and degradation to which the selected straps were subjected were:

- Conditioning A, method assimilated according to point 5.3.3/EN 443: 2008 [8, p. 15], ie the samples were subjected to the following cycle: 1 h at (-30 ± 2) ^{0}C, followed by exposure 1 h at temperature of (+60 ± 2) ^{0}C, immersion in water for 15 min at the temperature of (+10 ± 2) ^{0}C, 1 h at the temperature of (+60 ± 2) ^{0}C, 24 h at the standardized temperature of (+20 ± 2) ^{0}C and standardized relative humidity of (65 ± 5)%.
- Exposure to flame for 10 s: The method consisted of exposing the samples to the flame of a burner specified in EN ISO 15025:2017 [9] for 10 s. The burner flame in the horizontal standby position was adjusted to (25 ± 2) mm, the distance measured from the end of the burner to the extreme point of the yellow part of the flame. During the test the burner was positioned perpendicular to the test sample at a distance of (17 ± 1) mm measured between the end of the burner and the surface of the strap (see figure -1).

Figure 1 - Flame exposure system

- Exposure to contact heat for 60 s at 300 ^{0}C [4, p. 1669]. The equipment used was as described in section 8.7/EN ISO 20344 [10, p. 71] pg.71 (see figure - 2).

Figure 2 - Apparatus for testing the contact heat resistance

Impact Factor:

ISRA (India)	= **6.317**	**SIS** (USA)	= **0.912**	**ICV** (Poland)	= **6.630**
ISI (Dubai, UAE)	= **1.582**	**РИНЦ** (Russia)	= **3.939**	**PIF** (India)	= **1.940**
GIF (Australia)	= **0.564**	**ESJI** (KZ)	= **9.035**	**IBI** (India)	= **4.260**
JIF	= **1.500**	**SJIF** (Morocco)	= **7.184**	**OAJI** (USA)	= **0.350**

In order to follow the influence of the thermal risk factors present in the firefighting operations on the mechanical characteristics of the analyzed straps, the static resistance was determined both on the specimens in the initial state and on the specimens exposed to conditioning cycles and thermal risks. In case of exposure to thermal risk factors, the samples were conditioned for 24 h at a standardized temperature of (+20 ± 2) ^{0}C and a standardized relative humidity of (65 ± 5)%.

1.2. TEST RESULTS AND ANALYSIS

For the study, 3 types of strap were used (see Table 1), differentiated by materials, structure and dimensions.

Table 1. Selected samples

Sample code	Photo	Composition	Width, mm	Thickness, mm
1		100% polyamide (PA)	45	2,5
2		100% polypropylene (PP)	44	2,4
3		100% polyester (PES)	44	2,5

A set consisting of the 3 strap samples shown in Table 1 was prepared for each exposure. They were tested at a force of 15 kN for 3 minutes (see figure - 3) after being exposed to conditioning A followed by the exposure to fire and contact heat. The static resistance of the unconditioned (initial) straps, exposed to fire and contact heat, was also tested.

Figure 3 – Static resistance test stand

The results of the test series are presented in Table 2

Table 2. Static resistance after conditioning followed by exposure to fire

Cod eşantion	Foto	Observations after applying the force	
		Initial + exposure to fire	Conditioning A + exposure to fire
1		breaks at 13,3 kN	breaks at 11,5 kN
2		breaks at 9,2 kN	breaks at 7,8 kN

Impact Factor:

ISRA (India)	= **6.317**	**SIS** (USA)	= **0.912**	**ICV** (Poland)	= **6.630**
ISI (Dubai, UAE)	= **1.582**	**РИНЦ** (Russia)	= **3.939**	**PIF** (India)	= **1.940**
GIF (Australia)	= **0.564**	**ESJI** (KZ)	= **9.035**	**IBI** (India)	= **4.260**
JIF	= **1.500**	**SJIF** (Morocco)	= **7.184**	**OAJI** (USA)	= **0.350**

Cod eșantion	**Foto**	**Observations after applying the force**	
		Initial + exposure to fire	Conditioning A + exposure to fire
3		breaks at 8,6 kN	breaks at 7,9 kN

By performing the series of tests on the sets of samples in the initial state and exposed to conditioning A followed by the exposure to flame and mechanical strength, it was observed that regardless of the material from which the samples are made, they do not meet the static strength requirement.

Also, considering the results obtained, it can be said that the variations in temperature and humidity significantly influence the resistance of straps.

Regarding the exposure of the of sample sets in the initial state and exposed to conditioning A followed by exposure to contact heat the results are presented in Table 3.

Table 3. Static resistance after conditioning followed by exposure to contact heat

Cod eșantion	**Foto**	**Observations after applying the force**	
		Initial + exposure to contact heat	Conditioning A + exposure to contact heat
1		lasts 3 min	lasts 3 min
2		lasts 3 min	breaks at 10,6 kN
3		lasts 3 min	breaks at 13,8 kN

The analysis of the results mentioned in table 3 shows that regardless of the material from which all the belt samples are made, which were not conditioned but only exposed to contact heat, they withstood for 3 minutes the application of the 15 kN force.

By analyzing the results recorded in Tables 2 and 3 it can be concluded that successive exposures to large temperature variations (from -30 ^{0}C to 60 ^{0}C) accompanied by immersions in water, specific to conditioning A and frequently encountered in the case of activities at altitude, produce changes in fiber structure. As these changes cannot be observed in the case of periodic inspections, under the synergistic action of the various risk factors such as occasional contact with the flame and the occurrence of a fall from a height, they can lead to serious accidents.

Moreover, by analyzing the results obtained, it can be said that the static resistance depends both on the nature of the material from which the straps are made and on the nature of the risk factor. Thus, it can be said that the straps in PA have an increased resistance compared to those in PP or PES.

CONCLUSIONS

The results of the study tests showed that under the action of various risk factors (environmental conditions, fire, hot surfaces, etc.) the elements made of strap lose their protective characteristics. Due to this, it is considered necessary to test the components of personal fall protection systems considering the risk factors existing in the work environment. Therefore the development and implementation of the test methods specific to the existing risks in the workplace is considered imperative in establishing the appropriate protection characteristics.

ACKNOLEDGEMENTS

The paper received financial support through the research and development project PN 19 44 03 01 entitled "Studies and research on the synergistic action of new and emerging risks on the protection characteristics of personal equipment used against risks with serious consequences for the development of conformity procedures for assessment in accordance with the requirements of Regulation (EU) 2016/425 ".

References:

1. (2016). *REGULATION (EU) 2016/425 of the European parliament and of the council of 9 March 2016 on personal protective equipment and repealing Council Directive 89/686/EEC*.
2. Prostakishin, D. A. (2021). *V. A. A. R. S. G. a. A. Y. B. "Verification method of strength of refractory slings for positioning and holding after exposure to a heated metal rod,"* in Innovations and Technologies in Construction (BUILDINTECH BIT 2021).
3. Willi, J.M. (2016). *G. P. H. D. M. "Characterizing a Firefighter's Immediate Thermal Environment in Live-Fire Training Scenarios,"* in Fire Technology.
4. (2018). *EN 358:2018 „Personal protective equipment for work positioning and prevention of falls from a height - Belts and lanyards for work positioning or restraint"*.
5. (2002). EN 361:2002 „Personal protective equipment against falls from a height - Full body harnesses".
6. Prostakishin, D.A. (2021). *K. V. Z. R. S. G. a. A. Y. B. "Verification method of material stability of fire-resistant slings for holding and positioning against an open flame,"* in IOP Publishing Ltd.
7. (2008). *EN 443:2008 „Helmets for firefighting in buildings and other structures"*.
8. (2010). *EN 354:2010 „Personal fall protection equipment - Lanyards"*.
9. (2017). *EN ISO 15025 „Protective clothing. Protection against flame - Method of test for limited flame spread"*.
10. (2011). *EN ISO 20344:2011 „Personal protective equipment - Test methods for footwear"*.