

Measurements in flame retardant textiles and protective clothing using an instrumented manikin

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Abstract: The flame test manikin system can be used to evaluate the performance of thermal protective clothing under fire simulation conditions. Different weights of thermal protective garments were tested and the total clothed burn injury area decreased as the fabric weight increased. In addition, a comparison of different compositions for the same weight was analyzed too.

Keywords: Instrumented manikin, flame manikin, flame retardant protective clothing

1. INTRODUCTION

When clothing is exposed to intense heat or flames, polymers and other materials will suffer thermal degradation and combustion, which depend on parameters such as absorption of energy from heat flux (conductive, convective and radiant), molecular composition, formation of products like liquids, char and solid materials. However, the combustion characteristics are too complex, depending on the fabric fiber, cloth structure, moisture trapped in the fibers, nature of finishing and others [1]. In this scenario, flame retardant (FR) finishes are applied in fabrics to reduce clothing flammability and avoid melting or ignition when the garment is exposed to heat.

According to Torvi [2], flame resistance is defined as the property of a material whereby flaming combustion is slowed, terminated or prevented. Textile materials can become flame resistant through chemical treatments or by use of inherently flame-resistant fibers.

Chemically treated FR fabrics are produced by applying a flame retardant chemical finish to a

fabric or by adding a chemical treatment to the fibers before they are woven or knitted into the fabric. These flame-retardants form a strong bond with the polymer chain, modifying its molecular structure and for this reason, it is difficult to remove these chemicals by washing.

Inherently FR fabrics are made of fibers in which the FR properties are part of the polymer backbone like aramids.

The thermal protective performance of the textiles and garments can be evaluated using a variety of standard tests [3-4]. Bench-scale tests such as TPP test, RPP test and full-scale flame manikin test are the advanced methods employed to assess the protective properties of the materials aforementioned.

This study proposed to evaluate the performance characteristics of flame resistant clothing and the influence of the fabric weight in the predict burn injury using an instrumented manikin.

2. METHODOLOGY

2.1. Test apparatus

In this work, the tests were performed on an upright flame test manikin developed by Thermetrics (figure 1), which contains a 50th percentile Western male body form. Six groups of propane gas burners distributed evenly around the manikin generate the simulated flash fire expose, with average heat flux of 84 kW/m². A total of 134 copper calorimeter sensors, distributed on the manikin body, measure the total heat energy transmitted through protective clothing and this result is used to predict the degree of burn injury to human tissue.



Figure 1. The instrumented manikin of SENAI-CETIQT (front view on left and back view on right).

According to ASTM F1930-15 [5] and ISO 13506-08 [6], the prediction of skin damage related to second-degree and third-degree burn is determined using a skin model. In these tests the head, hands and feet were not included because these parts were not covered with the garment during the flame exposure.

2.2. Materials

In order to evaluate the influence of the weight in the prediction of burn skin damage, table 1 shows the six single layer protective clothing (overalls) tested in combination with t-shirt and underwear.

The exposure time was 3 seconds for all garments tested.

Table 1. Details of the samples

Garment	Textile composition	Weight (g/m ²)
I	88% cotton / 12% polyamid	237
II	88% cotton / 12% polyamid	250
III	88% cotton / 12% polyamid	260
IV	88% cotton / 12% polyamid	470
V	100% cotton	260
VI	100% cotton	290

Three samples of each garment type were measured and the results are given as mean values.

3. RESULTS AND DISCUSSION

Figure 2 summarizes the results of burn prediction for five different weights and two compositions.

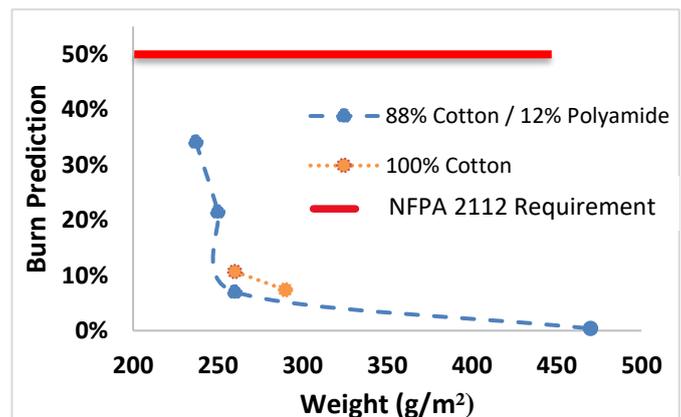


Figure 2. Variation of burn prediction with weight.

In both compositions evaluated, the burn injury decreases as the weight increases. The same

behavior can be stated when analyzing the same weight of 260 g/m² for different compositions. There is a slightly increase in burn injury for the composition of 100% cotton. It can be explained by the addition of synthetic fibers in the composition of the fabric that may improves the performance of the garment in the test, however there is a limit in this addition that must be obeyed [7].

Kotresh [8] studied the influence of fabric weight and burning rate of different fabrics vertically oriented during burning. He stated that the burning rate decreases as the fabric weight increases. The same pattern could be noted in the study proposed in this article. The results analyzed are the sum of second and third degree burn prediction, which is defined as the total clothed burn injury area.

For both, 88% cotton / 12% polyamide and 100% cotton, it is observed a decrease in the burn prediction as weight increases. Additionally, all the results of burn injury were below the maximum value of 50% stated by NFPA 2112 for flame resistant garments [9].

Figure 3 (a) to (d) shows the variation of burn prediction with time for 88% cotton / 12 %

polyamide (a) 237g/m², (b) 470 g/m², (c) 260 g/m² of weight and for 100% cotton (d) 260 g/m².

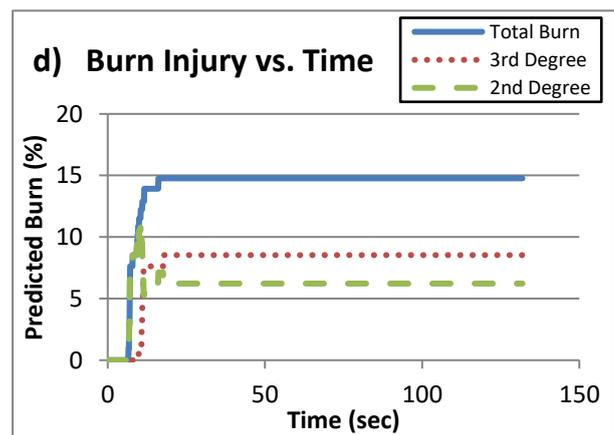
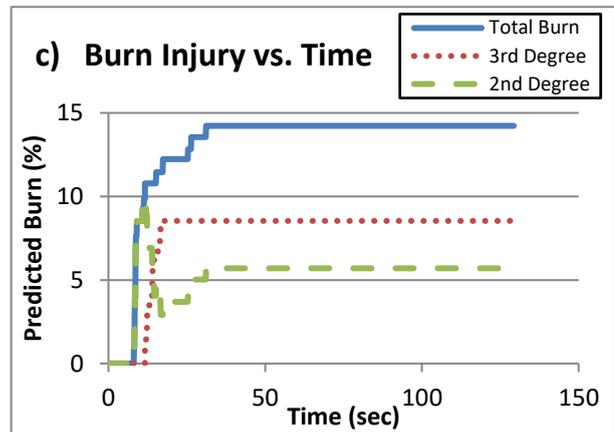
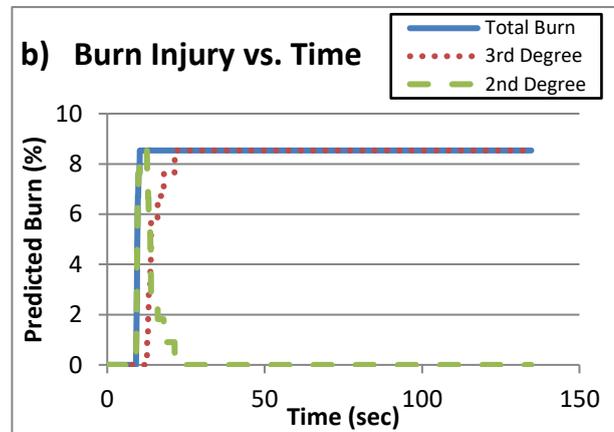
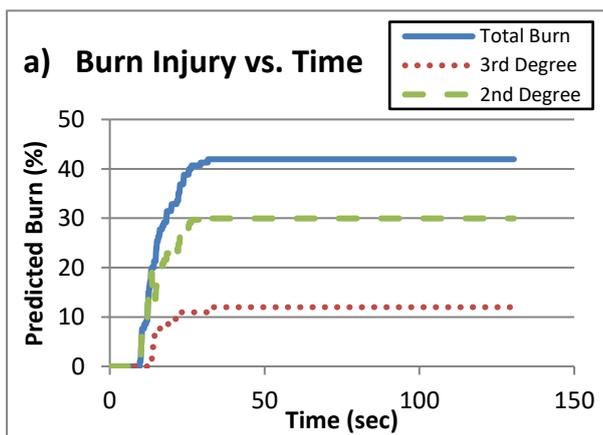


Figure 3. Variation of burn prediction with time for 88% / 12% Cotton / Polyamide (a) 237 g/m², (b) 470 g/m², (c) 260 g/m² and 100 % Cotton (d) 260 g/m².

4. CONCLUSION

Significant studies have been done in the field of thermal protective clothing. In general, the performance of thermal protective clothing can only be evaluated using an assessment based on an instrumented manikin due to the most real condition to simulate burn damage in human body.

This study indicates a tendency of decreasing of the total clothed burn injury area with the increasing of the FR fabric weight of protective clothing, tested in an instrumented manikin exposed of simulated flash fire expose, with average heat flux of 84 kW/m².

Nevertheless, regarding protective clothing used in industry, the association of safety and comfort is needed and an increasing of the weight fabric may not be the best option in order to improve the ergonomics for flame protective clothing.

Then, the study was satisfactory in relation to its purpose and it could be observed an inverse relation between fabric weight and predicted burn skin injury.

5. REFERENCES

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