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Katniss's flaming wedding dress in real life

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Abstract
This paper discusses the feasibility of the fire dress from "The Hunger Games: Catching Fire" in real life. It was decided that the dress could be made with two layers: one upper layer composed of cotton and one lower layer composed of a fire-resistant fabric, Kevlar The paper calculates the thermal current between the materials and determines the temperature transferred to the skin. Hence, it was concluded that the flaming dress could be worn for 5 seconds maximum and only under extra precautions.

Introduction

The latest sequel of "The Hunger Games" movie stunned thousands of women around the world with a fabulous flaming wedding dress, which was worn by Katniss during a television interview before the start of the Hunger Games (figure 1).

Figure 1. Katniss's fire dress [1]

As Katniss spun around, the dress caught fire, causing the upper white fabric to burn away and reveal the black dress underneath. It looked amazing in a movie, but would it be possible to create such a dress in real life? To achieve this, this paper tries to model a dress that would be made from two layers of different fabrics - Kevlar, fire insulating material, and cotton, known as the fastest burning fabric [2].

Designing the fire dress

Kevlar was chosen as the fire insulating material and hence placed beneath the cotton fabric to protect the skin from the fire. Kevlar is a unique material, because it does not melt, but degrades at relatively high temperatures (427°C - 482°C) [3]. Hence, in order to achieve a similar effect to the one seen in the movie Kevlar would need to be under the cotton layer that would be set on fire. However, in real life the heat from the fire might be unbearable for a human, even with the insulating material. Therefore, by calculating the thermal current between the materials it is possible to determine the amount of heat transferred to the surface of skin through the insulating material.

How hot it would get?

In order to determine the amount of heat produced by burning the dress, we can rearrange an equation for the thermal current [4]:

$$I = \frac{dQ}{dt} = -kA\frac{dT}{dx}$$

If we solve this equation for the temperature difference, we obtain:

$$\Delta T = I\frac{\Delta x}{kA}$$

which can be simplified to:

$$\Delta T = IR$$

Hence, for the thermal current we get:

$$I = \frac{\Delta T}{R}$$

where *I* represents thermal current, *R* is thermal resistance and ΔT is the change of temperature. Therefore, we need to find the thermal resistances of both Kevlar and skin. They can be calculated by applying the equation of the thermal resistance is:

$$R = \frac{x}{kA}$$

where *x* is thickness of material, A is area and k is thermal conductivity. An average wedding dress requires approximately 18m^2 of fabric [5], meaning we would need the same amount of Kevlar under the upper layer of the dress. Also, the average thermal conductivity of Kevlar is 0.06 W/mK [6] and the assumed thickness of Kevlar is 0.03m. Hence,

$$R(kevlar) = \frac{0.03m}{0.06W/mK\ x\ 18m^2} = 0.027m^2K/W$$

In order to calculate thermal resistance for skin we know that the area of human skin is approximately 2m^2, thickness is 0.003m and thermal conductivity is 0.37 W/mK [7]. Hence, the thermal resistance is:

$$R(skin) = \frac{0.003m}{0.37W/mK\ x\ 18m^2} = 0.0041m^2K/W$$

Now that we have the thermal resistance of Kevlar and skin we can determine the thermal current of the burning dress to see how much heat would be transferred to the surface of skin through the insulating material. Hence, in this case the equation would be:

$$\mathrm{I} = \frac{\Delta T}{R(kevlar) + R(skin)}$$

Also, the burning point of the cotton is 210°C [8] and we know that the normal temperature of human body is 36.6°C. Hence,

$$I = \frac{210°\mathrm{C} - 36.6°\mathrm{C}}{0.027m^2K/W + 0.0041m^2K/W} = 5575.5\ W$$

Then we can calculate the temperature difference across the Kevlar [4]:

$$\Delta T = IR(kevlar) = 5575.5W\ x\ 0.027m^2KW = 150.54°\mathrm{C}$$

Now we are able to determine the temperature at the interface between Kevlar and the skin:

$$T = 210°\mathrm{C} - 150.54°\mathrm{C} = 59.45°\mathrm{C}$$

According to the American Burn Association 60°C hot water can cause a third degree burn after 5 seconds [9]. Meaning, that the safest amount of time to wear a flaming dress would be maximum 5 seconds.

Conclusion

Knowing that water as hot as 60°C can cause severe burns after 5 seconds, it can be concluded that a flaming dress could be worn for a maximum of 5 seconds. However, this paper did not consider the fact that the dress is sleeveless so flames could easily the harm hands, neck and other body parts that are not protected from the fire. Also, as a dress would require at least 3cm of Kevlar, most women would not wear it, because it would make them look at least 2 sizes bigger. As a result, a flaming dress like the one described would be suitable only for adrenaline fans that would like to try the dress only for the purpose of science or fun.

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