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Life in Plastic ... Is it Fantastic?

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Abstract

"I'm a barbie girl, in a barbie world – life in plastic. It's fantastic." Was a bold statement made in the 1997 song titled 'Barbie Girl' by Aqua. This song is about the famous dolls Barbie and Ken where they sing about their fun, playful existence where they party. But is it fantastic? Yes, fun and partying are enjoyable activities for some; but does life in plastic bear the same fruits? In this paper 15% of the body is explored as composed of plastic.

Keywords: Song; Biology; Physics; Plastic; Skin; Conduction; Young's Modulus; Aqua; Barbie

Introduction

Barbie is a series of fashion dolls produced by Mattel in 1959. Barbie was created because Ruth Handler, co-founder of Mattel, recognised that her child was playing less with her toy baby dolls but more with paper dolls [1]. A doll named Lilli, a gag doll marketed to men originally, insighted interest in children, and was a sort of case study that led to the creation of the Barbie dolls we know today. When Handler encountered Lilli, she believed that it was possible to make an 11.5-inch doll with different costumes [2].



Figure 1 – Barbie doll posing for 2014 sports illustrated cover [2].

Since the first model Barbie has been re-released: constructed with better materials, a plethora of experience on her CV and many different costumes and accessories. The Barbie doll has also had companions be manufactured like her boyfriend Ken who was released in 1961 [1].

In 1997 a group called Aqua released a banger, if you will, titled 'Barbie Girl' [3]. The song states *"I'm a barbie girl, in a barbie world – life in plastic. It's fantastic"* [4]. This song highlighted the significance

of Barbie, and the statement appears to hold true to many. Plastic surgery has been on the rise and become a more casual occurrence for people to aspire to unrealistic proportions or features for their body. People have also emulated Barbie's appearance using plastic surgery. However, plastic surgery is not actually plastic; it derives from the Greek Word 'Plastikos' which means to mould or form [5]. While people try to recreate the appearance of this plastic doll, this paper will see whether if a human was made up of plastic, like Barbie, if it could be fantastic.

Barbie Materials from Old and New Models

Barbie is a complex toy made of many materials. In this paper we will focus on the components that are not accessories, clothes etc. The old barbie was rotation moulded with soft vinyl and its hairline was stitched in; the colours for barbie are typically gold or brown saran [6]. The old barbie was not very environmentally friendly and caused acid rain when disposed of by incineration due to the PVC forming hydrochloric acid. There were also concerns because when the barbie doll was ingested by children the compound formed in the stomach, upon reaction with stomach acid, would leave behind a hard material [6]. New environmental laws meant the new barbie was produced differently as the amount of plasticizer in the PVC of the old model was unideal [6]. The new Barbie materials: a custom PBT formulation called "Silkstone" with impact modifiers and mineral filling, EVA (ethylene-vinyl acetate) in her

arms, ABS (acrylonitrile-butadiene-styrene) in her torso, polypropene, PVC outer legs, hard vinyl compound head [6]. Barbie is also hollow and has paint.

Barbie Skin

The Young's Modulus of human skin has a range of between 5 kPa and 40 MPa [7]. Skin's main function is to act as a barrier against physical injury and thermal injury, it has pores and the components to facilitate sensations [8].

Material	Young's Modulus	Melting Point (°C)	Thermal Conductivity W/mK
PBT	1.93 – 3 GPa [9]	219.85 – 266.85 [9]	0.2741 – 0.2851 [9]
EVA	15 – 80 MPa [10]	90 – 120 [13]	0.23 – 2.85 [14]
ABS	1.79 – 3.20 GPa [11]	220 – 230 [15]	0.14 – 0.21 [16]
Polypropene	0.4 – 13.50 GPa [11]	165 [17]	0.1 – 0.22 [16]
PVC	0.001 – 7.00 GPa [11]	100 – 260 [18]	0.12 – 0.25 [16]

Table 1 – Young's Moduli, Melting point and thermal conductivity of materials that make up Barbie.

The data in table 1 shows that the plastic components used in Barbie have a large range for their Young's Modulus so in terms of elasticity it is plausible to replace human skin with plastic, as a key function of skin is to act as a physical barrier without restricting movement. Tiny holes can act as sweat pores.

Fourier's law of heat conduction equation 1 [19] was used to calculate the heat transfer to the plastic from the body:

$$Q = UA\Delta T = \frac{k}{s}A\Delta T, \quad (1)$$

where Q is the heat transfer (W), U is the coefficient of heat transfer (W/(m²K)), k is the thermal conductivity of the material (W/mK), s is the material thickness (m), A is the heat transfer area (m²) and ΔT is the temperature gradient across the material [19]. This is used to calculate heat transfer across skin which gives:

$$Q = \frac{0.187}{0.006} \times 2 \times (310 - 298) = 748W. \quad (2)$$

Inputting values of 0.187 W/(mK) for skin thermal conductivity [1], skin thickness of 6 mm [20], skin surface area 2 m² [21], we get a value of 748 W for heat transferred between the internal body (at temperature of 310 K [22]) to the external

environment. In this case the environment is the plastic layer at room temperature (298K). The thermal conductivity data in table 1 shows that the rate of thermal flow can be the same as skin. The thickness calculated using equation 1 would lead to skin thickness varying from 3 – 91 mm depending on the plastic used for the rate of thermal flow to be 748 W. Replacing skin with plastic is possible and could be fantastic but this only considers 3% of body heat which is lost via conduction [23].

Skin protects us from UV radiation [8]. However, with plastics UV rays can cause photooxidative degradation in which polymer chains are broken and produce free radicals which results in the plastic losing its mechanical viability and this occurs in an unpredictable time [24]. Polypropylene has also been noted as a plastic at a higher risk of UV degradation [25]. Which is not fantastic.

Cells in Plastic

Functioning neural cells have been shown to grow in a dish [26]. Heart tissue capable of beating has also been made as well as many more important body parts and organs have been produced in petri dishes which can be made of plastic [27]. Most of these techniques began with pluripotent stem cells and they have not yet been associated to the human body but have been either tested in isolation with connection to electrodes [26] or on animals such as monkeys or rats [27].

Conclusion

Looking at the materials of Barbie in terms of mechanical function and thermal capacities skin can be replaced with plastic, which amounts to 15% [28] of the body being fantastic in plastic as you could still theoretically party. Nevertheless, further research is required as only heat transfer via conduction was considered. Infection blockage is an important function of skin and with the plastic model containing pores (for sweat), this has not been considered so it is likely that an individual with plastic skin would frequently be susceptible to infection (not fantastic). Further development of nanomaterials to replace neural cells and more with tiny petri dishes could make life in plastic feasible and fantastic and increase the estimated value, if we consider this for organs and afore mentioned cell tissue [26, 27] and estimate half of the organ mass [29, 30, 31, 32] can be replaced with plastic this could bring the plastic percentage to approximately 17% [28]. But why would you want to do any of this anyway?

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