P1 8 Blasters, Beskar and the Physics of Heat Transfer

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Abstract

This paper estimates the physical requirements for the fictional material *beskar* from *The Mandalorian* to resist a high-energy blaster bolt. Using thermodynamics and heat transfer principles, we model the blaster bolt as a plasma bolt and calculate the resulting temperature rise and heat distribution in a breastplate of armour. We find that if a bolt deposits 342 MJ of energy into a few kilograms of optimised armour, the local temperature change would exceed approximately 2.00×10^4 K, which is enough to vaporise any known material. To survive, *beskar* must possess exotic thermal and structural properties beyond current materials science.

Introduction

The Mandalorian is a *Star Wars* spin-off series centered on Din Djarin, a bounty hunter belonging to the Mandalorians. The Mandalorians are renowned for their distinctive armour, crafted from the legendary *beskar*, a material sought after across the galaxy for its extraordinary ability to withstand blaster fire [1]. Blasters operate by converting energy-rich gas into plasma bolts, delivering intense bursts of heat [2]. This raises the question: how could any material resist the energy density of a plasma bolt? To explore this, we estimate the heating effect of a blaster impact on a breatplate of real-world armour. By comparing the energy of a fictional blaster bolt with known thermal properties of materials such as iron, osmium, carbon fibre and diamond, we can assess whether *beskar*'s resilience is plausible under physical laws.

Modelling the Blaster Bolt

We begin by assuming a single blaster shot carries an energy, E, of 342 MJ [3], and strikes a breastplate of realistic iron armour with dimensions 30.0 cm × 30.0 cm × 1.00 cm. The impact volume is then 9.00×10^{-4} m^3, and since the density of iron is 7870 kg m^{-3} [4], the impact mass, m, is 7.08 kg. The temperature change, ΔT, of the iron breastplate due to this impact can be calculated using the specific heat formula:

$$E = mc\Delta T \Rightarrow \Delta T = \frac{E}{mc}, \qquad (1)$$

where c is the specific heat capacity of iron, 440 J kg^{-1} K^{-1} [4]. The temperature change is therefore $\Delta T \approx 2.00 \times 10^5$ K. This is enough to vaporise any known material. In order to make this temperature change more reasonable, *beskar* must be much denser than iron and must have a considerably higher specific heat capacity.

Optimising our Armour

In order to reduce the temperature change of the breastplate due to the blaster bolt, more dense materials must be considered. Osmium is one of the densest naturally occurring elements, with a density of 22600 kg m^{-3} [5]. Reevaluating

our impact mass of a breastplate of the same volume with this new density gives us, $m = 20.3$ kg. The temperature change can also be decreased by increasing the specific heat capacity of our breastplate. When considering state at room temperature, stability and practicality, carbon fibre is an appropriate candidate with a specific heat capacity of 900 $\text{J kg}^{-1}\,\text{K}^{-1}$ [6]. Substituting our new impact mass using Osmium and our new specific heat capacity using carbon fibre into Equation 1, we get a new temperature change of $\Delta T \approx 2.00 \times 10^4$ K. While this temperature change is still far too high for our armour to match the efficiency of *beskar*, we are getting closer to something more reasonable.

Considering Conductivity

As well as considering the integrity of our breastplate, such as its density and specific heat capacity, the efficiency at which it spreads the heat of the blaster bolt must also be considered. Heat spreads through a material according to its thermal diffusivity, α:

$$\alpha = \frac{\kappa}{\rho c}, \tag{2}$$

where κ is the thermal conductivity. Thermal conductivity is the measure of a material's ability to conduct heat. Returning to our standard iron breastplate, its thermal diffusivity can be calculated using Equation 2 and the fact that iron has a thermal conductivity of 80.2 $\text{W m}^{-1}\,\text{K}^{-1}$ [4]. Therefore, the thermal diffusivity of iron is 2.32×10^{-5} $\text{m}^2\,\text{s}^{-1}$. As we are discussing the transport of plasma, the distance heat diffuses, l, during a pulse of duration t can be approximated [7]:

$$l = \sqrt{\alpha t}. \tag{3}$$

If we model the impact of a blaster bolt to last for 1.00 ms, then the distance the heat diffuses is 0.152 mm. This is far less than the breastplate thickness, so the heat from the blaster bolt would stay localised and vaporisation would be unavoidable. A *beskar* breastplate must have a much higher thermal conductivity and thermal diffusivity than iron in order to distribute the heat from a blaster bolt. In the real world, diamond is one of the most efficient thermal conductors known, with a thermal conductivity of 2000 $\text{W m}^{-1}\,\text{K}^{-1}$ [8]. Substituting this into Equation 2, the thermal diffusivity of a diamond breastplate is 1.12×10^{-3} $\text{m}^2\,\text{s}^{-1}$. Note that the density of diamond is 3510 kg m^{-3} and its specific heat capacity at room temperature is 510 $\text{J kg}^{-1}\,\text{K}^{-1}$ [8]. Modelling another 1.00 ms blaster bolt using the thermal diffusivity of diamond and Equation 3, the distance the heat diffuses is this time 1.06 mm. While this is still considerably smaller than the thickness of our breastplate, the heat from a blaster bolt is more efficiently distributed when the breastplate is made of a material with a high thermal conductivity.

Conclusion and Discussion

The closest real-world *beskar* breastplate would consist of a hypothetical combination of osmium, carbon fibre and diamond. Osmium provides a high density, carbon fibre a high specific heat capacity and diamond a high thermal conductivity. It should be acknowledged that it would be unrealistic for the combination of these materials to have the exact thermal properties of each individual material that we want. However, even when considering this best case scenario, our real-world breastplate still gets instantly vaporised by a 342 MJ blaster bolt. Then when considering the distribution of this heat, it would still be far too localised to mitigate any damage. *Beskar* cannot be reproduced using real-world materials, however, the physics of *beskar* is not totally unreasonable. It can be concluded that *beskar* must be composed of an exotic combination of materials beyond 21$^{\text{st}}$ century knowledge with extraordinarily high density, specific heat capacity and thermal conductivity in order to resist a blaster bolt.

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