P2 1 Whether Wonder Woman's Wearables Would Work

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Abstract

In this paper we discuss the most appropriate modern-day material that Wonder Woman's bracelets would likely be made out of, according to the apparent characteristics and ability to reflect bullets demonstrated in the comics. We decide that carbon nanotubes are the best material candidate due to their light weight nature and having a high Young's Modulus allowing it to maintain a low thickness while still absorbing a bullet's energy elastically. This would be thin and light enough to be wearable, but would compromise and not reflect the metallic appearance of the bracelets in the comics.

Introduction

Wonder Woman is a comic book character created in 1941. She has a plethora of superpowers and special fictional equipment that allow her to fight threats and protect innocent people in the stories she features in. Notably, she carries a "lasso of truth" and the "bracelets of submission" [1] - the latter of which exhibits magical properties that we investigate and discuss in this article. The bracelets can deflect bullets and other attacks, and we will investigate the properties of them to suggest a non-fictional material for these fictional items to be made from.

Method

Wonder Woman has many feats of strength, including lifting and throwing the Washington Monument. The Monument has a mass of approximately 82×10^6 kg [3]. Given that the bracelets are worn casually, we use this feat to set an upper mass limit for the bracelets of 82×10^4 kg.

The most common comic book usage of the bracelets is to deflect bullets. We shall start by discussing the energy of the bullets and use this to evaluate the impact of them striking the bracelets. Kinetic energy is defined as:

$$KE = \frac{1}{2}mv^2, \qquad (1)$$

Where the velocity of a standard 115 grain 9mm bullet is typically 332 m/s at 22.86 m [4], and the mass of the bullet is approximately 8 g [4].

To identify the material the bracelets are made from, we can look for the Young's Modulus that would represent a material able to withstand a bullet strike. For this we assume that the bracelet only undergoes elastic deformation and all the energy of the bullet is transferred to the bracelet during the collision. Therefore applying the work-kinetic energy theorem to the collision:

$$KE = W = \int \vec{F} \cdot \vec{dr}, \qquad (2)$$

We relate the kinetic energy to the elastic energy density, u stored by the bracelet due to the

impact:

$$u = W/V \qquad (3)$$

Where V is the impact volume defined by the bullet cross section A and the thickness of the bracelet, t

$$V = At \qquad (4)$$

Considering a stress-strain curve, this elastic energy density can be expressed in terms of the compressive stress σ and strain ϵ experienced by the bullet during the collision [5].

$$u = \int \sigma(\epsilon) d\epsilon \qquad (5)$$

Where in the elastic region, the stress and strain are linearly related such that:

$$\sigma(\epsilon) = E\epsilon \qquad (6)$$

where E is Young's Modulus of a given material. Combining equations 2 through 6 and performing the integration, after some simple rearrangement, we arrive at the result:

$$t = \frac{2KE}{A\epsilon^2} \cdot \frac{1}{E} \qquad (7)$$

We can now plot this to investigate which materials are most appropriate for the bracelets, based on the thickness required for only elastic deformation to occur. We note that the kinetic energy is determined by equation 1 where the mass and speed are known and that the bullet cross section is defined by having a diameter $d = 9 \, \text{mm}$ for a 9mm bullet. We have chosen a strain of 5% as a modest approximation to the durability displayed in the comics.

Discussion & Conclusion

As seen in the comics [1], The bracelets would need to be a few mm thick at most. Referring to Figure 1, we see that typical metals like steel or tungsten would need to be several cm thick to provide the durability we require. A more novel material like carbon nanotubes would provide the same durability at much lower (sub cm) thicknesses, although this contradicts the metallic appearance seen in the comics. Therefore,
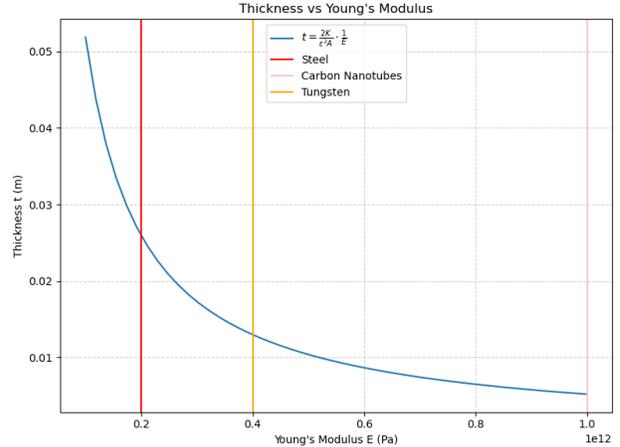

Figure 1: The relationship between the Thickness of the material and the Young's Modulus, with the x-axis ranging from 0.1 to $1TPa$ and the Young Modulus of steel, tungsten and carbon nanotubes also highlighted [6][7].

of our candidate materials, carbon nanotubes are the appropriate choice for constructing the bracelets due to their high durability while maintaining a reasonable thickness.

Modelling the bracelets as a hollow cylinder with a thickness t, any choice of material is significantly lower than the mass limit we proposed in the method, and so weight is not a concern for construction, although we note that carbon nanotubes have much lower density and therefore make lighter bracelets than a traditional metal bracelet.

This conclusion is reached using assumptions that try to compromise between the physical reality and the mythical nature of the comic books. Crucially, we have assumed that elastic deformation occurs as the only consequence of the collision on the bracelet and modelled the strain as a maximum of 5% to represent the invulnerability of the comic bracelets. In reality, there would be plastic deformation and a range of strains that could be experienced, which would introduce complications to the model and likely change our result as the materials would be subject to more extreme deformations and damage.

References

[1] All star comics vol #1 Gardener Fox, Everett E. Hibbard (1942)

[2] Wonder Woman Vol 6 issue #6, Tom King, Daniel Sampere, Tomeu Morey (2024)

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[4] `https://www.ammunitiontogo.com/lodge/9mm-ballistics/` (Access date 30/09/2025)

[5] Physics for Scientists and Engineers, P. A. Tipler and G. Mosca, Freeman, New York, 2007. P. 693. (page 409)

[6] `https://www.engineersedge.com/manufacturing_spec/properties_of_metals_strength.htm` (Access date 30/09/2025).

[7] `https://www.je-depa.com/Training/Tutorial/Appendix/YM%20for%20common%20materials.html` (Access date 30/09/2025).