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P4_6 Wind swept

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Abstract

This paper discusses the plausibility of the thrusters in the Iron Man suit being used as weapons to push a human back. It was determined that the shock-wave produced by the change in temperature due to the thrusters would produce a force of 183 kN on a person it was shot at, this would cause the person to accelerate at 2614 ms^{-2}, likely killing the person.

Introduction

In the Marvel extended universe the character Tony Stark (the 'Iron Man') uses a powered exoskeleton to fight crime. In recent incarnations of the character the Iron Man suit provides the wearer with super strength, the ability to fly and is filled with an assortment of weapons. In this paper we will be focusing on small energy-based thrusters that sit in the palms of the hands and soles of the feet. We will use the energy required to produce small bursts of 'flight' (more akin to jumps) to deduce whether or not they could actually propel a person a short distance away backwards if 'fired' at them.

To determine whether the Iron Man suit is capable of such a 'pushback', the change in temperature of the air in front of the thrusters needs to be calculated. For this paper, the initial force of lift-off is assumed to be provided by rapidly heating the air under the suit's thrusters, this 'ΔT' is found by equating the weight of the suit to the force provided by an near-instantaneous increase in pressure below caused by the temperature change.

From visual inspection the thrusters are assumed to be circles of radius $r = 0.03$ m and the suit taken as roughly 0.01 m thick, Tony Stark is assumed to weigh 70 kg with a surface area of 1.9 m^2 [1]. In the films the Iron Man suit is said to be made from a 'titanium-gold alloy', this paper will use $\beta - Ti_3Au$ due to it being four times stronger than pure titanium [2]. From Fig.1 of the referenced article, this compound has a density of approximately 800 kgm^{-3} (from Fig.1 of the article). Using the density, surface area and thickness of the suit, we find it to have a mass of 15.2 kg, giving an overall mass to be lifted, m, of 85.2 kg.

$$P_1 = \frac{nRT_1}{V} \tag{1}$$

$$P_2 = \frac{mg}{A} = \frac{nRT_2}{V} \tag{2}$$

$$n = \frac{\rho_{air} V}{M_{mol}} \tag{3}$$

The symbols in the ideal gas equations above have their usual meanings, with P_1 and P_2 being initial and final pressures, m is the mass of the suit, A is the area over which the pressure change acts, n is the number of moles of air, with ρ_{air} being the density of air at T_1 of 1.225 kgm^{-3}, and M_{mol} the molar mass of air, 0.0290 kgmol^{-1}.

Rearranging equations (1),(2) and (3) gives an equation for the change in temperature required to change pressure by the requisite amount:

$$\Delta T = T_2 - T_1 = \frac{mgV}{AnR} - \frac{P_1 V}{nR} \tag{4}$$

Using the above figures gives a ΔT of 258 K.

$$C = \left(\frac{\gamma P_1}{\rho}\right)^{0.5} \tag{5}$$

$$P_2 = \frac{2\rho v^2}{\gamma + 1} \tag{6}$$

To calculate the push-back received by a person at range, we model the shock-wave caused by the rapid increase in air temperature around the thruster, using equations (5) and (6)[3], we use the sound speed C in the expanded gas (assuming instantaneous expansion) as the value for v in the second equation, using the density of air at T_2 of 0.4 kgm^{-3} for P_1 and a γ of 5/3, this gives a sound speed of 948 ms^{-1}.

Using this velocity, the pressure of the shock-wave becomes 270 kPa. Over the full frontal area of a human of 0.68 m^2 [4], this amounts to a force of 183 kN. If this force was applied to a person within one meter, the radial fall off of the shock-wave would be negligible; because of this the force that the person would experience due to the shock-wave would easily knock a person back, with an average acceleration , given by $F = ma$, of 2614 ms^{-2}. This would likely kill anyone that it would hit, as the human body cannot survive an acceleration of 266 g.

Conclusion

The Marvel character Tony Stark's Iron Man suits' energy-based thrusters use the temperature change of the air under the thrusters to provide an upward force to induce flight, this temperature change was found to be 258 K. These thrusters can also be used as weapons by producing a shock-wave, it has been calculated that a person hit by this would feel a force of 183 kN, this amount of force would result in an acceleration of 2614 ms^{-2}, likely resulting in the death of anyone hit by it.

References

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