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A4_7 Falling Angels & Demons

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Abstract

This paper investigates the chance of survival when jumping out of a high-flying helicopter. First it is found that the related scene described by Dan Brown in 'Angels & Demons' is plausible, and then a different case is considered. By considering the balance of forces and drag caused by using a piece of fabric as an improvised parachute, it was found that a landing on a solid material would very likely cause a fatality whatever the case. However a landing in water may be survivable with good form and an 4XL t-shirt.

Introduction

Dan Brown, the author of the popular book "The Da Vinci Code" has written several other novels including "Digital Fortress", "Deception Point" and "Angels & Demons" (A&D). A&D followed the progress of protagonist Robert Langdon as he attempts to stop the murders of several papal-candidates after the death of the pope. The story takes him all around Rome and includes attempting to defuse an 'anti-matter bomb', which eventually gets dealt with by putting it in a helicopter and flying up into the clouds. [1]

After reaching what he feels is a safe height for the people below, the helicopter's pilot Camerlengo Carlo Ventresca reveals that there is unfortunately only one parachute and takes it as he dives out of the cockpit. This leaves Langdon in a very bad situation – stuck in a helicopter with a very powerful explosive device and incapable of bringing it down. He decides to evacuate the aircraft and grabs the helicopter's window-cover (a large piece of fabric used to cover the windows) to use as an improvised parachute. He is able to successfully make his way down to earth and lands in the Tiber River, apparently without major injury. [1]

This paper estimates some of the forces in such a situation and then considers what would happen if a passenger had to attempt the same stunt using clothing as an improvised parachute.

Theory

It can be assumed that the occupants of the helicopter reached 2.5km into the air, to hit the lower cloud layers. This is sufficient to allow any falling body to reach terminal velocity (in fact only around 460m would be necessary) where the forces acting upwards (drag force) and downwards (gravitational force) balance.

In such a situation the drag equation [5]

$$F_D = \frac{1}{2}\rho C_d A v^2 \qquad (1)$$

can be used where F_D is the upwards force due to air resistance, ρ is the density of the medium (in this case it is air, 1.225kgm^{-3}), C_d is the coefficient of drag (which depends on the shape of the object), A is the area facing the drag and v is the speed of the object.

Equating this to the falling person's weight and rearranging gives the terminal velocity in terms of the area of the 'parachute' as

$$v = \sqrt{\frac{2mg}{\rho C_d}} A^{-\frac{1}{2}} \qquad (2)$$

where m is the person's mass (assumed to be roughly 75kg) and g the acceleration due to gravity, 9.81ms^{-2} (this is neglecting the contribution to drag that the person himself may produce, so the real upwards force would be even larger). This is also useful as it can be rearranged to find the terminal velocity of a body given its area.

Additionally the buoyant force F_B on an object displacing a volume of water V_{disp} can be written as [10]

$$F_B = \rho_f V_{disp} g \qquad (3)$$

where ρ_f is the density of water (1000kgm^{-3}). This can be equated to the force $F_{\Delta KE}$ necessary to cause a change in kinetic energy over distance d [9]

$$F_{\Delta KE} = \frac{\Delta \frac{1}{2} m v^2}{d} \tag{4}$$

to give the distance into water an object would travel before coming to rest as

$$d = \frac{\frac{1}{2} m v^2}{\rho_f V_{disp} g}. \tag{5}$$

Discussion

Estimates of the size of a window-cover give it as being around 3.91m×1.90m×3.40m, although it could be around as small as 1.96m×1.9m×2.5m. [2] First the larger size was modelled as a hemisphere (giving a drag coefficient of 1.5 [3]) to give an estimate of the drag caused, and then the smaller measurements were used to create a parallelepiped (that has a drag coefficient of 1.28 [3]) to calculate a more accurate value. In the first case A is then approximately 10.41m^2 while in the second it was 8.46m^2 (considering the two faces opposing motion). This resulted in terminal velocities of 8.77ms^{-1} and 9.73ms^{-1}, which are both surprisingly low for such a large descent – in fact they are only slightly larger than those achieved with proper parachutes, comparable to a jump from 4m high. Assuming a volume of 0.075m^3 and that the parachute detaches upon contact, such speeds would result in travelling 3.92m and 4.83m into water respectively.

This surprising result prompted the consideration of other improvised parachutes – what would be the outcome of using say a shirt or t-shirt? It was found that with a medium size t-shirt (51cm by 74cm) the surface area would result in a speed of 56.4ms^{-1} and a 4XL (76cm by 86cm) gives a terminal velocity of 42.87ms^{-1}. [6]

Conclusion

As shown above, Robert Langdon's fall from a helicopter is apparently a fairly safe stunt – provided the window cover can be secured to him and arranged in such a way that it creates a lifting force. Furthermore he would only need around a 5m deep volume of water to come to a stop. The case for someone creating a parachute out of their clothing is not so clear cut. The speeds of over 40ms^{-1} in both cases are extremely dangerous in any situation. How could this be made safer? A person with such a dilemma may think to aim for a body of water for a softer landing, but this is not advisable as travelling so fast means the surface-tension of water will act similarly to concrete. [7] However if they could decrease their speed slightly more, it may be their best bet.

To give some context to the success of the improvised parachutes with a water landing, consider the world record high-dive. The record stands at 172ft (52m) and from that height the diver would hit the water at about 32ms^{-1}. It is incredibly dangerous, as an attempted dive from 177ft (only 1.5m higher) proved – the result being that the diver broke his back. [8] However if a 4XL shirt was ripped open to double its surface area, and held in such a way that it was effective, it could potentially slow you down to 30.31ms^{-1} and with a good dive may save your life.

References

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