Journal of Physics Special Topics
An undergraduate physics journal

A1 1 Without a Parachute

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October 28, 2024

Abstract

American Skydiver Luke Aikin nearly had his world record attempt cancelled over safety concerns. He eventually jumped from a plane without a parachute as planned, landing safely in a net. This paper will evaluate the safety concerns, showing that the approximate 12 kg of weight from the parachute would have added nearly 30% to the stopping force, a significant margin that could have led to disastrous, and fatal, consequences.

Introduction

In 2016 American Skydiver Luke Aikins sought to break the world record for highest skydive without a parachute, falling from approximately 7.6 km above Southern California. However, the day before the stunt was set to take place, organisers insisted Akins wear a parachute anyway in case of an emergency. Aikins explained his counterargument on record, saying that "the added weight of a parachute would increase the force of the impact and make the jump more dangerous" [1]. Aikins eventually performed the feat as planned, plummeting safely into a custom made net known as the "Fly Trap", and walking away unharmed to celebrate his new record. This paper seeks to evaluate Luke Aikins' counterclaim that jumping with the parachute would have lessened the safety, not increased it, specifically because the added mass would have posed a danger due to its influence on the force of the impact.

Calculations

To begin with some assumptions: it is assumed that Aikins reached his terminal velocity near-instantaneously, and secondly, that his surface area (A) can be modelled as a rectangle of 1.7 m by 0.5 m, so that $A = 0.85$ m^2. To find the terminal velocity (v_t), the following formula was used:

$$v_t = \sqrt{\frac{2mg}{\rho A C_d}} \tag{1}$$

Here, m is the mass of Aikins (approximated to the average human mass of 70 kg), g is gravitational field strength (at a value of 9.81 N/kg), ρ is the density of air (at ~ 1 kg/m^3), A is as previously mentioned, and C_d is his coefficient of drag (1.05 for a rectangular shape). This gives a v_t of 39.2 m/s.

Aikins' net (the Fly Trap) was made from a material called Spectra (chosen for being completely inelastic) [2] and supported on all four corners by air-based suspension. We assume that upon Aikins hitting the net, the force of his fall is transferred into the net (moving it from resting to v_t) near instantaneously ($\Delta t = 0.1$ s) . Thus, the impact force (F_I) will be:

$$F_I = m\frac{v_t - v_f}{\Delta t} \approx 27.5 \text{ kN}, \tag{2}$$

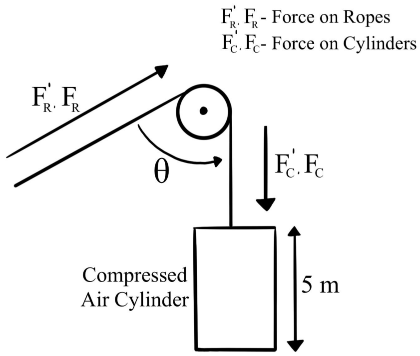

Figure 1: One of four compressed air cylinders designed to absorb the force of Aikins' fall

Assuming he hits the centre of the net so the force is distributed evenly to all four corners, this is 6.88 kN of force going up each support rope (F_R). These support ropes are attached to the pylons containing the shock absorbers via a pulley at an angle (θ) of approximately 60° (See Figure 1). Therefore the force going into each pylon (F_C) is $6.88\cos(60°) = 3.44$ kN. Now that the force of the impact on the safety equipment has been found, we need to identify what impact this had. As discussed before, the structure has air-based suspension comprised of approximately 5 m tall cylinders (l) which compress in order to dissipate the force upon them. To find this change, we rearrange the bulk modulus (K) formula for direct stress and volumetric strain:

$$K = \frac{\sigma}{\epsilon_V} = \frac{(\frac{F_C}{A})}{(\frac{\Delta V}{V})} \tag{3}$$

for the volumetric extension:

$$\Delta V = \frac{F_C l}{K} \tag{4}$$

and with the bulk modulus of air being 1.01×10^5 Pa, this gives $\Delta V = 0.17$ m^3 for Aikins' jump. Now, to evaluate Aikins' claims, we repeat these calculations with the added parachute mass. Adding a parachute into the equation (of typical mass 12 kg [3]) increases the total mass of Aikins by 17.1%. The new impact force (F'_I) (Equation 2) is now 34.9 kN, or 8.73 kN per rope (F'_R) and $F'_C = 4.37$ kN per cylinder (under the same assumptions as before). This increases the change in volume (Equation 4) to 0.22 m^3.

Discussion

Therefore, the added mass of the parachute would have added approximately 26.9% to the stopping force, raising the 3.44 kN to 4.37 kN per air piston. Perpetuating through, the air inside each piston would also need to be compressed a further 26.9%. This is a significant margin, as the Fly Trap was observed to be very delicate during practice attempts. One rehearsal saw the pistons configured incorrectly, and the sand bag dummy plummeted straight through to the ground [4]. Bearing in mind that the decision was still being appealed in the moments before the stunt began, the net was configured to the lower mass. It can thus be inferred that Aikins was valid in his objection to the parachute mandate.

Conclusion

Luke Aikins' statement has been shown to be valid. The added mass would have increased the stopping force by nearly 30%, which these researchers argue is a significant enough margin to pose a credible threat to Aikins' safety through the added stress on the stopping mechanisms.

References

[1] `https://deadline.com/2016/07/heaven-sent-sag-aftra-skydiver-lands-safely-1201795897/` [Accessed 29th September 2024]

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[4] `https://createdigital.org.au/extreme-engineering-luke-aikins-skydive/` [Accessed 30th September 2024]