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A4_5 Mars Airport

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Abstract

This report looks at the use of air transportation on Mars for the purpose of manned missions. Differences in atmospheric density and gravity on Mars compared with on Earth were used to compare transport methods. For a Balloon it was found that on Mars it would have to have 76 times larger volume than on Earth. Aeroplanes and helicopters are also discussed and it was found that helicopters are a much more feasible option then the other forms of transport.

Introduction

The goal of many space agencies is to land humans on Mars, ultimately leading to semi-permanent scientific outposts. This report seeks to discuss the different sorts of air travel that could be used to move around on Mars and then compare them to counter-parts on Earth. The three different types of travel that shall be looked at are balloons, aeroplanes and helicopters.

Designs for the different machines would have to vary from the Earth versions due to the lower gravity and different atmospheric conditions. For example the strength of gravity on Mars is 3.73m/s^2 [1] compared with 9.81m/s^2 on Earth.

The atmospheric density of Mars differs greatly to the density of the atmosphere on Earth due in part to the different elements that it is composed of, as well as the different pressure, P. To find the density the mean molecular weight of the Martian air is needed, this is found by adding together the fractional components times the number of grams per mole to give the molecular mass, $M^*=43.47$ *g/mol* [2]. This can then be put into equation 1 which is the ideal gas law, rearranged for density, ρ.

$$\rho = \frac{M^* P}{RT}. \qquad (1)$$

Using the average temperature, T, on Mars as 218K, and pressure P, of 0.0063atm gives an atmospheric density of 0.015kg/m^3 [2]. With this data the different types of transport can be discussed.

Balloon

To look at the case of using balloons then the forces are balanced [3]. Equation 2 shows this balance, where M is the mass of the balloon, m is the mass of the payload and m_{He} is the mass of the helium gas used.

$$Mg = \rho_a g V - mg - m_{He} g\ . \qquad (2)$$

Where ρ_a is the density of the atmosphere, g is the gravitational acceleration and V is the volume of displaced gas. Rearranging equation 1 and substituting in for the mass of helium with its density, ρ_{He} and volume used, then equation 3 is achieved.

$$(M+m) = (\rho_a - \rho_{He})V\ . \qquad (3)$$

By comparing the differences in the density it is possible to find any changes needed in the volume to lift the same mass on Earth as on Mars. The density of the helium on Mars was calculated the same way as the atmospheric density, this was calculated as 0.0014kg/m^3.

Putting in the values of the densities of air and helium on Earth (1.2 and 0.16kg/m^3 respectively [4]) and Mars (as stated above) while setting the left hand side of the equation 3 constant, it is found that the volume of helium would need to be 76 times larger on Mars than Earth to lift the same total balloon and payload mass. This equates to a radial factor increase of 4.23 if using a spherical balloon.

Aeroplane & Helicopter

For the case of aeroplanes and helicopters then Bernoulli's equation, equation 4, is applied above and below the wings and rotor blades respectively [5].

$$B = \frac{P}{\rho_a} + \frac{c^2 v^2}{2} + gz\,. \qquad (4)$$

Where *c* is a constant factor depending on the shape of the wing, *z* is the altitude of the craft and *v* is the velocity of the craft. The cases of above and below (*c*=1) wing or blades are set equal and rearranged for the lift force per unit area, F_l (from the difference in pressure),

$$F_l = (1/2)(c^2 - 1)v^2 \rho_a\,. \qquad (5)$$

So for the same mass to be lifted on Earth and Mars the equation becomes,

$$\frac{v_E^2 \rho_E A_E}{g_E} = \frac{v_M^2 \rho_M A_M}{g_M}\,. \qquad (6)$$

Where *E* subscript represents the case on Earth and *M* subscript for Mars, whilst *A* is the area of the wingspan of a plane or area swept out by a helicopters main rotor. By putting in the constants, then what is obtained is,

$$30 A_E v_E^2 = A_M v_M^2\,. \qquad (7)$$

Using this equation it was possible to create a graph, figure 1, that shows the variations for factor increases in area and velocity for the same total mass of aircraft on Earth as would be used on Mars.

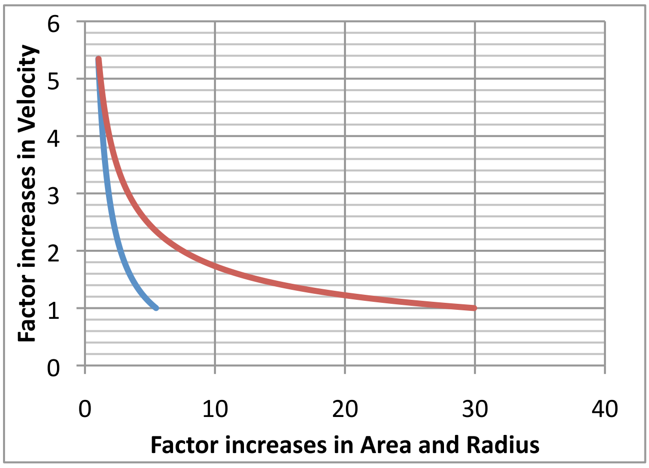

Figure 1. A graph showing factor increases needed for an aeroplane/helicopter to fly on Mars, the red line is for area increases and blue line is for increases in the radius of rotors of helicopters.

Discussion

Due to the increases in volume (and mass of a balloon) on Mars needed to lift the same mass on Earth, resulting in a decreased payload capacity, a balloon is not a feasible possibility for manned transport on Mars. However it has possibilities for unmanned experiments, as have been investigated by NASA and other space agencies for moving a small scientific payload (<100 kg) over large amounts of the Martian landscape [6].

Aeroplanes would be useful for transporting a large amount of equipment for manned bases. As equation 7 can show for use on Mars there has to be either a 5 times increase in the velocity of the craft, a 30 times increase in the area of the wingspan, or a mixture of the two as seen in figure 1a. Figure 1b shows the velocity of a helicopters blade against the radius of a blade. The graphs show that while the same area and velocity increases would be necessary for a helicopter and plane, for the helicopter the radius of the rotors can be looked at. It is observed that a factor of 2 increases to the rotor size requires a factor of 2.5 increases in the velocity, which is an easier feat to achieve than a factor 5 increase in the area of the aeroplanes wings.

Conclusions

The conclusion that is drawn from these results are that balloons are good for use for small-scale long-term unmanned exploration. While for large scale manned transports over the Martian surface helicopters are more feasible due to small changes needed to the structure (easily modified rotor area) and output of the engines than for planes.

References

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