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(57) Abstract

A projectile traversing the lower atmosphere at hypersonic speed suffers high aerodynamic drag. This may be reduced by preheating the air ahead of it to create a "plasma tunnel", within which the temperature is raised to several times the ambient with a corresponding reduction in density, reducing the drag force. Typically, overall drag may be reduced by a factor of 10-100 in this way. The heating may be accomplished in several ways. For example the projectile may be equipped with a prove attached to the nose through which liquid is sprayed. The liquid is brought to rest by the surrounding air, converting its kinetic energy to heat. A particular application is to electromagnetic space launch systems. A projectile accelerated to orbital or escape velocity at ground level by linear accelerator can traverse the atmosphere with acceptable speed loss.

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HYPERVELOCITY DRAG REDUCTION

DESCRIPTION

This invention relates to a technique for diminishing the drag force, and also the frictional heating, to which high velocity projectiles travelling within the atmosphere are subject.

The concept is to heat the air in front of the projectile. As the absolute temperature of a gas is raised, its density decreases by a corresponding factor (for a given external pressure, at equilibrium). For example if a column of air in front of the projectile is heated to 3,000 degrees Kelvin and allowed to expand freely, it will form a 'tunnel' with a density about one-tenth that of the surrounding air. The drag force on the projectile will decrease by a corresponding amount. The heating of the front surface of the projectile will also be reduced.

Many different methods of heating may be used. These include electromagnetic energy (e.g. by microwave or laser radiation), chemical reaction (e.g. by releasing a substance which combines with atmospheric oxygen) and kinetic heating, in which energy of motion (of the projectile itself, or material released from the projectile, or from another source) is dissipated. The heating may be performed by equipment on the projectile itself, or on the ground, or on another vehicle (for example, a second 'trail-blazing' projectile which precedes it in the same course).

The technique is applicable to any vehicle which traverses a medium sufficiently dense to cause significant retardation and/or heating. It is especially relevant to vehicles which travel at hypersonic velocity within the lower part of the Earth's atmosphere. These include spacecraft launched directly from the Earth's surface at orbital or escape speed using linear accelerators.

Specific embodiments of the invention will now be described by way of example.

EXAMPLE 1

A ten-kilogram projectile is fired vertically from a railgun at sea level at a speed of 12 km/sec. Attached to the nose is a forward-pointing hollow metal pipe. Liquid nitrogen is pumped along this (incidentally serving to cool the pipe against atmospheric heating) to emerge as a fine spray.

The nitrogen mixes with a larger mass of atmospheric air to form a plasma at temperature 6,000 degrees Kelvin. This plasma expands to about 20 times its original volume. Thus a cylinder of air which was originally one-quarter the diameter of the projectile expands to fill a cylinder slightly wider than the projectile itself. The drag force on the projectile is decreased by a corresponding amount.

If the projectile has frontal area 0.01 m2 and aerodynamic coefficient Cd = 0.2, without this protection it would lose half its speed to air resistance. With the protection speed loss is reduced to 2%.

Heating the air requires approximately 6 million J/kg. Dissociation of the oxygen in it consumes a further 0.5 million J/kg. (Almost no nitrogen dissociates at this temperature.)

At 12 km/sec, each kilogram of mass carried in the projectile has 72 million Joules kinetic energy. Thus 1 kg of nitrogen from the projectile heats approximately 10 kg of air, and only one-twentieth of the air which originally occupied the space in front of the projectile is heated. So the on-board nitrogen reservoir uses 0.5 kg during the whole atmospheric traverse = 5% of projectile weight.

Additional benefits could include:

1. The air impacted by the nitrogen released is pushed forward, and so impacts the projectile nosecap at slightly reduced relative velocity, further diminishing the drag force.
2. The oxygen contained in the air has dissociated, decreasing the mean molecular weight and so further reducing the density.
3. Heating on the projectile surface is reduced. (This benefit may be traded by making the projectile more streamlined. An unprotected projectile would need an ablative nosecap and must be quite blunt. A protected projectile could be needle-nosed, with the heating absorbed into the metal skin, with Cd up to 10 times lower, further reducing drag loss.)

The weight of the nose probe must also be allowed for. Its optimum length relative to the projectile radius may be approximated by dividing the projectile speed by the speed of sound in the surrounding air: ratio 40 = 2.2 metres forward of the widest part of the projectile. Maximum pumping rate is approx 1 kg/sec giving internal diameter of a few millimetres. In practice the probe will widen towards the base, being integrated into the projectile nose shape. The nitrogen will be expelled from a pressure reservoir at the appropriate rate by a pressurizing gas.

N.B. Nitrogen is chosen becuse of its high dissociation temperature. Other choices are of course possible, for example liquid argon. If water is used, it would dissociate, absorbing 23 MJ/kg energy. The high specific volume of the hydrogen generated would however tend to counterbalance this disadvantage at very high speeds.

EXAMPLE 2

A 20 tonne projectile is released from a horizontal linear accelerator at 9 km/sec at a shallow upwards angle (vertical speed 900 metres/sec) at a point 3,000 metres above sea level. The projectile is 2 metres in diameter with Cd 0.2.

It is protected by releasing liquid nitrogen from a probe attached to the nose, to create a 6,000 degree Kelvin plasma tunnel, as in the previous example. Total speed loss will also be 2%: the longer atmospheric traverse is compensated by higher mass per frontal area. The nitrogen required will weigh 10% of total projectile weight, however, because its specific kinetic energy is only 40 MJ/kg at this lower speed.

EXAMPLE 3

A hypersonic aircraft releases liquid hydrogen from a probe attached to its nose. This combusts with the oxygen in the surrounding atmosphere to raise its temperature to 3,000 degrees Kelvin, lowering the drag on the aircraft body by a factor of 10.

EXAMPLE 4

A hypersonic projectile has a rigid spike of material attached to its nose. This heats the air which impacts it, ahead of the main projectile, creating a heated gas tunnel as in the previous examples.

EXAMPLE 5

One projectile/vehicle precedes another. It heats the air it passes through creating a heated gas tunnel for the benefit of the second vehicle (by direct friction, or by releasing an inert or combustible substance, etc.).

This concept exrtends to a 'train' of a larger number of projectiles, each assisting the passage of those following.

EXAMPLE 6

A ground installation fires a beam of electromagnetic energy (e.g. laser or microwave radiation) to heat the air ahead of a projectile. The projectile might help to intercept or focus this energy. For example it might release a 'plasma dopant' to promote the formation of a plasma capable of absorbing the energy transmitted; or focus a microwave beam to a point forward of its nose by diffraction or other effects.

EXAMPLE 7

A ground installation fires a beam of electromagnetic energy (e.g. laser or microwave radiation) to create a tunnel of hot air through which a projectile/vehicle subsequently passes.

EXAMPLE 8

A projectile, or string of projectiles in succession, are fired to create a heated gas tunnel through which another projectile/ vehicle subsequently passes. The projectiles might for example be fired by railgun, or descend from an orbital installation.

EXAMPLE 9

A fuze of solid propellant hangs vertically from a helicopter or balloon, or is fired ballistically from a line gun, or trailed behind an aircraft. It detonates, or burns from the end, to create a heated gas tunnel as previously described. The projectile may be launched when combustion is complete, or alternatively follow the fuze as it burns.

EXAMPLE 10

A projectile as in any previous example, but using a stream of gas or powder or pellets (as distinct from a liquid) to heat the air.

EXAMPLE 11

A column of air is heated by vibration (e.g. by focussed ultrasound) to provide the heated tunnel effect.

EXAMPLE 12

A rocket motor or jet engine on the ground fires its exhaust upwards (or a jet of heated steam or air from any source is used) to provide a column or mass of superheated air or other gas(es) through which a vehicle or projectile is subsequently passed.

EXAMPLE 13

A powder, vapour, liquid or gas is 'sowed' through a volume of the atmosphere. Its subsequent ignition provides a heated tunnel.

EXAMPLE 14

The passage of a projectile or vehicle through the atmosphere is assisted by a combination of the preceding methods.

CLAIMS

1. A system for reducing the atmospheric drag on a projectile travelling through an atmosphere at high speed, characterized in that air ahead of the projectile is heated and consequently expands, reducing the density per unit volume of the gas impacted by the projectile.
2. A system for reducing the heating of the surface of a projectile travelling through an atmosphere at high speed, characterized in that air ahead of the projectile is heated and consequently expands, reducing the density per unit volume of the gas impacted by the projectile.
3. A system for reducing both the atmospheric drag on, and the heating of the surfce of, a projectile travelling through an atmosphere at high speed, characterized in that air ahead of the projectile is heated and consequently expands, reducing the density per unit volume of the gas impacted by the projectile.
4. A system as claimed in claim 3, further characterized in that the projectile is highly streamlined, so further reducing the atmospheric drag.
5. A system as claimed in claim 4, further characterized in that the projectile nosecone does not ablate.
6. A system as claimed in claim 5, further characterized in that the heating on the projectile nosecone is absorbed into the (metal) skin.
7. A system as claimed in claim 3, further characterized in that the heating of the air ahead of the projectile is accomplished

wholly or partly by electromagnetic energy.

8. A system as claimed in claim 3, further characterized in that the heating of the air ahead of the projectile is accomplished wholly or partly by chemical combustion.

9. A system as claimed in claim 3, further characterized in that the heating of the air ahead of the projectile is accomplished wholly or partly by kinetic heating.

10. A system as claimed in claim 9, further characterized in that the kinetic heating is accomplished by the projectile's own kinetic energy.

11. A system as claimed in claim 8 or claim 9, further characterized in that the heating is accomplished by material released from the projectile.

12. A system as claimed in claim 11, further characterized in that the material released emerges from a forward-pointing pipe attached to the projectile nose.

13. A system as claimed in claim 12, further characterized in that the material pumped along the pipe serves the additional purpose of cooling the pipe against atmospheric heating.

14. A system as claimed in claim 8 or claim 9, further characterized in that the heating is accomplished by means of a leading 'trail-blazing' projectile.

15. A system as claimed in claim 8 or claim 9, further characterized in that the heating is accomplished by means of material released from a leading 'trail-blazing' projectile.

16. A system as claimed in claim 8, further characterized in that the combustive heating is accomplished by releasing liquid hydrogen into the surrounding air.

17. A system as claimed in claim 9, further characterized in that the kinetic heating is accomplished by releasing liquid nitrogen into the surrounding air.
18. A system as claimed in claim 10, further characterized in that the kinetic heating is accomplished by air friction on a forward-pointing spike attached to the main nosecone of the projectile.
19. A system as claimed in claim 14, further characterized in that a train of trail-blazing projectiles, rather than a single one, is used.
20. A system as claimed in claim 3, further characterized in that the heating of the air ahead of the projectile is accomplished wholly or partly by atmospheric vibration (sound energy).
21. A system as claimed in claim 3, further characterized in that the heating of the air ahead of the projectile is accomplished wholly or partly by a fuze of combustible or explosive material which has been placed along the path it will follow.
22. A system as claimed in claim 3, further characterized in that the heating of the air ahead of the projectile is accomplished wholly or partly by combustible or explosive material which has been distributed (as a powder, liquid, vapour or gas) in the atmosphere along the path it will follow.
23. A system as claimed in claim 3, further characterized in that the heating of the air ahead of the projectile is accomplished wholly or partly by, or the air ahead of the projectile is wholly or partly replaced by, the exhaust from

a jet or rocket engine.

24. A system as claimed in claim 7, further characterized in that electromagnetic energy fired from a source other than the projectile is focussed into the air ahead of the projectile with the assistance of equipment upon the projectile.

25. A system as claimed in claim 7, further characterized in that electromagnetic energy is absorbed by the air ahead of the projectile with the assistance of a substance (such as a plasma dopant) released into this air.

26. The use of a system as claimed in claim 3 to permit a projectile fired from a ground-based linear accelerator to reach space retaining sufficient speed to permit insertion into Earth orbit or escape trajectory.

27. The use of a system as claimed in claim 3 to permit a projectile fired from a horizontal ground-based linear accelerator and deflected upwards at a shallow angle to reach space retaining sufficient speed to permit insertion into Earth orbit or escape trajectory.