Re: The Dual−stage 4−grid Ion Thruster

Source: http://sci.tech−archive.net/Archive/sci.space.history/2005−12/msg00330.html

- *From*: Rémy MERCIER <Rmy.MERCIER.1zt49n@xxxxxxxxxxxxxx>

- *Date*: Sat, 10 Dec 2005 00:22:09 +0000

meiza Wrote:
> "frédéric haessig" fhaessig@xxxxxxx wrote:
>
> "meiza" meiza@xxxxxxxx a écrit dans le message de news:
> dnats5pbb1@xxxxxxxxxxxxxxx
> Rémy MERCIER Rmy.MERCIER.1zqsxn@xxxxxxxxxxxxxx wrote:
>
> with isp = 19200s
>
> Huh, quite a great isp, but where do you need such a thing?
>
> Several possible reasons.
>
> 1) lower consumable mass. This means higher useful payload (for a
> given
> launch vehicule)
>
> As I explained, propellant mass ratios get ridiculously low but
> the *power source mass* grows by the specific impulse.
> (if you keep same thrust.)
> Even with isp as low as 3100−3500 s (deep space 1), and a mass ratio
> of 1.2, you get over 5 km/s of delta v. That is for example
> a 1000 kg dry mass probe with 200 kg of propellant.
>
> Deep Space 1 had total mass of 500 kg, of which used
> fuel was 74 kg. (ratio 1.15) It gained 4.3 km/s of
> speed when thrusting for over 400 days. The engine
> used 2.1 kW of power.
>
> Let's take that probe and do nothing but increase isp
> 5−fold to 17500.
>
> Use basic Newtonian equations:
>
> P = 0.5*(−dm/dt)*v_ex^2 , power
> F = (−dm/dt)*v_ex , thrust
>
> Since power stays the same, we can solve

> mass flow:
> −dm/dt=2*P/v_ex^2
> and thus the thrust is:
> F = 2*P/v_ex
>
> So the thrust drops to one fifth.
> When the original deep space 1 had thrusted for 400
> days and gained 4.3 km/s of speed, our new probe
> would have gained less than 1 km/s.
> Only after 2000 days (5.5 years), we would be going
> that speed. Sure, we would have used fuel only about 10 kg,
> but whether it's 10 or 70 kg, that is only a vanishingly small
> mass of the whole 500 kg probe.
> Our new probe would eventually reach a 20 km/s delta v,
> but it would take still 4 times more time, so it would
> last in total close to 22 years to reach full speed.
>
> So, one can say, let us increase power so that the high−isp
> design can accelerate as fast as the original. But this
> asks for 5X the solar cells. The original had two 5m long
> "wings". Even if we saved 60 kg in
> the form of fuel, it is not enough to make
> four more of those for 8 kilowatts. It's hard to get
> good figures for achievable solar cell power density, but
> one quoted number is 10 kg/kW. This would make the
> new cells weigh 80 kg. I don't know about the power
> electronics.
>
>
> 2) Continuous thrust transfer. Hohman transfer (aka minimum energy
> transfer) take a lot of time when you go to target far away.
> Continuous
> thrusting reduces this by a big factor.
>
> I don't know about this but are you sure you can get to a target
> faster by thrusting low for one year compared to getting the same
> delta−v
> in one hour? Or one month? Seems counter−intuitive.
>
>
> 3) In−space maneuvering. Either attitude correction or orbit changes.
> When
> you want to visit several celestial objects with the same mission (
> like a
> planet and several of its moons) or change orbit around a single
> object.
>
> Deep Space 1 had hydrazine for attitude control (actually running out
> of that
> forced mission end), as did Smart−1.
> Ion engines are probably not very good for that (at least directly)...

> the
> turning rate gets very slow, and if your solar arrays point in the
> wrong
> direction and you'd need an attitude correction, you can't use the ion
> engine
> because, uh, your solar arrays are pointing in the wrong direction. :)
>
> If you want to visit several moons in one mission, you're talking
> Jupiter or
> beyond, and then you don't do much with solar cells and have to use
> lower
> power per kg nuclear energy. If you need more delta v, it makes less
> mass to
> put in more fuel than to put more nuclear power and increase isp.
> Europe
> so far hasn't invested in nuclear space power sources.
>
>
> The usual problem with ION thruster is not Too high an Isp (as if
> there was
> such a thing) but too low a thrust level level for some applications.
> It
> seems technology is slowly solving this.
>
> The low thrust is precisely because of high power needed which is
> precisely
> because of the high isp. This is Newtonian physics and it can't be
> solved any
> other way than by higher mass efficiency power sources.
>
> Higher isp in ion engines automatically means less thrust for same
> power.
> There is no way around that.
>
> Why bother optimising for fuel efficiency if your already oversize
> motor
> is weighing more than the fuel tank. Only if you're going for a
> *really*
> long trip so that the fuel tank actually starts to matter.
>
> So that's why I was asking. High (3000) isp is not useful unless you
> start
> talking about much more than 5 km/s deltavees or alternatively really
> low mass power sources.
>
> I think Beppi−Colombo to Mercury will use Hall effect thrusters with
> about 1500 isp, like Smart−1.
>
> Does anyone have links or references to ion engine power system
> masses?
> (Solar cells, electronics, thrusters.) It's really hard to find

> anything
> in the net.
>
> −−
> −meiza

hydrazine? Why? You can use a lithium battery when your solar arrays
are pointing in the wrong direction.

About Beppi−Colombo I wonder if the next generation Hall thruster will
be ready (dual stage, 6kw and higher isp, near 2000s).

And more interresting, since a few months there is a strong interest
about the HDLT: (Helicon Double Layer Thruster):
http://tinyurl.com/bss28
http://tinyurl.com/a3ga6
http://www.esa.int/gsp/ACT/propulsion/helicon_double_layer.htm
http://www.abc.net.au/catalyst/stories/s1185537.htm

"""Europe so far hasn't invested in nuclear space power sources."""
Yes but there is a CEA team (french) working on this questions for ESA
and the russian could help with their thermoionic technology.

To go far and fast (Mars) we need a great tug: 70% mass = solair cells
and structure, propellant=20% and cargo=10%

−−
Rémy MERCIER
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- ***Follow−Ups***:
  - ♦ ***Re: The Dual−stage 4−grid Ion Thruster***
    - ◊ *From:* meiza

- ***References***:
  - ♦ ***The Dual−stage 4−grid Ion Thruster***
    - ◊ *From:* Rémy MERCIER
  - ♦ ***Re: The Dual−stage 4−grid Ion Thruster***
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  - ♦ ***Re: The Dual−stage 4−grid Ion Thruster***
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