

# 20231002TranscriptChatGPT4HelicopterISPandWaterImpele r



tahanson43206

GPT-4



Hello Again! It is Monday, 2023/10/02 at 15:19 local time - we've been discussing ISP as used as a measure of performance of a rocket engine. I am wondering if it makes sense to attempt to estimate the ISP of a hovering helicopter? The mass of the helicopter **\*\* must \*\*** be matched by the mass of air thrown downward by rotating helicopter blades. The velocity of the air mass thrown down is relatively low compared to a rocket engine, but the mass of the air is at least equal to the mass of the helicopter. What additional information would be needed to calculate the ISP of a hovering helicopter?

ChatGPT

The concept of specific impulse (



$I$

$sp$

) is not typically applied to helicopters or any other air-breathing propulsion systems because it's a measure specifically designed for rocket propulsion, relating the thrust produced to the rate of consumption of propellant mass.

However, if we would like to attempt a conceptual comparison or approximation, specific impulse for any system can be generally described by the equation:

$$I_{sp} = \frac{F}{\dot{m} g_0}$$

$I$

$sp$

$=$

$m$

$\cdot$

$g$

$0$

$T$

Where:

- $sp$

- $I$

- $sp$

- 

- is the specific impulse

- $I$

- $T$  is the thrust

- $\dot{m}$

- $m$

- 

- is the mass flow rate of the propellant (or, in this conceptual case, air)

- $g_0$

- $g$

- $0$

- 

- is the acceleration due to gravity at Earth's surface (

- $9.81 \text{ m/s}^2$

- $9.81 \text{ m/s}^2$

- $2$

- )

To attempt to compute a similar measure for a helicopter, we would need to know:

Thrust (T): For a hovering helicopter, this would be equivalent to its weight (mass times gravity).

Mass flow rate (

$\dot{m}$

$m$

.

) of the air being displaced: To calculate this, you would need to know the density of the air, the volume of air being displaced per unit time, and the velocity of the displaced air.

In a simplified scenario, if you know the helicopter's weight (mass times gravity), the density of air (

$\rho$

$\rho$ ), and the velocity at which the air is being displaced downwards

$v$

$v$ , you can try to estimate the mass flow rate (

$\dot{m}$

$m$

.

) as:

$\dot{m} = \rho \cdot A \cdot v$

$m$

.

$= A \cdot v \cdot \rho$

Where



$A$  is the area through which the air passes.

Then, use this



$m$

.

to find a makeshift



$I$

$sp$

for the helicopter:

$$\diamond \diamond \diamond = \diamond \diamond \cdot \diamond 0$$

$I$

$sp$

=

$m$

.

$g$

$T$

Do note that this is not a standard or rigorous way to compare a helicopter to a rocket, but more of a conceptual thought experiment.



Would you agree that the density of air can be chosen as that of standard temperature and pressure?

ChatGPT

Yes, using the air density at Standard Temperature and Pressure (STP) would be a reasonable starting point for this kind of conceptual approximation. At STP, the density of air is approximately

1.225  $\frac{\text{kg}}{\text{m}^3}$

1.225  $\text{kg/m}^3$

3

. However, bear in mind that the actual density of the air where the helicopter is operating could vary depending on the altitude, humidity, temperature, and atmospheric pressure at that specific location and time. For more accurate calculations, these factors should be taken into account, and the actual air density should be used.

But, if you're just doing a rough calculation or conceptual comparison, the STP value is often sufficient.



So far so good! Now ... I wonder how to obtain the velocity of the air propelled downward by the helicopter blades. It seems unlikely that anyone has bothered to measure this, but perhaps it can be calculated from the operation of the helicopter blades themselves. It should be possible to discover the rate of rotation of the helicopter blades, the length of the blades should knowable, and the mass/weight of the helicopter should be knowable.

ChatGPT

Yes, you can approximate the downward velocity of the air by using principles of conservation of momentum and the known parameters of the helicopter and its rotors. This is a rather simplified approach, and real-world computations would need to consider blade aerofoil, angle of attack, losses due to tip vortices, etc., but for a conceptual approximation, it can serve the purpose.

Rotor Disk Area: To begin with, you can find the rotor disk area (

$\diamond$

$A$ ) from the rotor diameter (i.e. twice the rotor blade length):

$$\diamond = \diamond (\diamond / 2)^2$$

$$A = \pi (D/2)^2$$

2

where

$\diamond$

$D$  is the diameter of the rotor disk.

Induced Velocity: In hover, the velocity of the air being accelerated downward by the rotor is called the induced velocity (

$\diamond \diamond$

$v$

$i$

). For a single rotor helicopter in hover, the induced velocity can be estimated by equating the thrust produced by the rotor (which is equal to the weight of the helicopter,

$\diamond \diamond$

$mg$ ) to the momentum flux of the air through the rotor disk:

$$\diamond = \diamond \cdot \diamond \diamond = \diamond \diamond \diamond \diamond 2$$

$$T =$$

$$m$$

.

$v$

$i$

$$= \rho A v$$

$i$

2

where:

- $T$
- $T$  is the thrust, equal to the weight of the helicopter (mass
- $\times$
- $\times$  gravity).
- $\rho$

- $m$
- $\dot{m}$

- is the mass flow rate of the air.
- $\dot{m}$
- $v$
- $i$
- 
- is the induced velocity (the speed of the air being accelerated downward).
- $\rho$
- $\rho$  is the air density.
- $\rho$
- $A$  is the rotor disk area.

Solving for the induced velocity (

$\dot{m}$

$v$

$i$

) gives:

$$\dot{m} = \rho A v_i$$

$v$

$i$

=

$$T/(\rho A)$$

This will give you a rough approximation of the downward velocity of the air due to the rotor in hover.

Use Induced Velocity for

$\dot{m}$

$I$

$sp$

Calculation: Then, you can use this induced velocity value as the velocity in your makeshift specific impulse calculations, together with the rotor disk area and air density to find the mass flow rate and then the specific impulse.

$$\dot{m} = \rho \cdot A \cdot v$$

$$m$$

$$\cdot$$

$$= A \cdot v$$

$$i$$

$$\cdot \rho$$

$$\dot{m} = \rho \cdot A \cdot v$$

$$I$$

$$sp$$

$$=$$

$$m$$

$$\cdot$$

$$\cdot g$$

$$0$$

$$T$$

Remember, this is a simplified model and actual values may differ due to many complexities involved in helicopter aerodynamics.



Thank you for participating in this thought experiment! I am attempting to communicate a (relatively new) concept for spacecraft propulsion to a skeptical audience, and the first challenge presented is whether the new system can support its own weight at the surface of the Earth. In casting about for examples of systems that do that, the idea of a helicopter came to mind. Any rocket that succeeds in rising above the surface of the Earth is (by definition) lifting its own weight, so the request is sensible. Thus, it would be a useful demonstration of a new rocket propulsion technology if it could lift its own weight at the surface of the Earth.

ChatGPT

Absolutely, a propulsion system capable of generating thrust equal to or exceeding its own weight (plus the weight of its fuel) is fundamental for liftoff from Earth's surface. This basic principle is what allows rockets, and indeed helicopters, to defy gravity and lift off the ground.



When discussing spacecraft propulsion to a skeptical audience, it might be helpful to relate it to concepts they are familiar with, like the hovering of a helicopter or the lift-off of a rocket, as you have been doing. It can also be beneficial to discuss the specific advantages and innovations of the new propulsion concept, and how it compares to existing technologies, in terms of efficiency, scalability, feasibility, and other relevant parameters.

Drawing parallels between established technologies and new concepts can indeed provide a familiar frame of reference and may help in conveying the feasibility and potential of the new idea. The thought experiment you've conducted with the helicopter can serve as an illustrative example of how a system can generate thrust to support its own weight, even though the actual mechanics and efficiency can be very different between a helicopter and a rocket.

It sounds like you are on a fascinating journey with your work on spacecraft propulsion. Best of luck in communicating your ideas and findings!



Rather than close this session at this point, I've decided to bring you in on previous work you and I have been doing. The challenge at hand is to find a way to use the thermal energy from a nuclear fission power plant to provide thrust to deliver a 5000 metric ton spacecraft to Mars. The NERVA concept is interesting, but it uses hydrogen. Water was considered but discarded early on, due to insufficient ISP. Ion drives such as VASIMR are able to produce thrust at a very high ISP, but the amount of thrust produced is very small, because ions are (by definition) very small, and the accelerator can only move a relatively small number at a time. In our previous correspondence, as you pondered the challenge, the idea of using physical devices to move water came up. A nuclear fission reactor can deliver 33% of its thermal energy output to electrical devices, such as motors to drive a rotor of a centrifuge. The remaining 67% of the thermal energy can be expended melting ice from the propellant supply. Thus, the system could, if it can be made to work, could harvest dirty water from a comet, and restock the propellant tanks. In this scenario, the debris that will inevitably come along with the water could be thrown by the centrifuge along with the water, assuming some modest filtering to exclude any material that would damage the system. The aerospace engineer who is the intended recipient of this proposal has already requested that the flow from the system be continuous rather than periodic, as had originally been proposed. This requirement leads to the vision of a spiral shaped physical accelerator that can deliver a stream of water at high velocity and in significant volume. I am not aware of such a physical system, but I do know that a spiral design is in present and effective use for compressing gases. Can you find in your training data any

examples of a spiral water throwing device? There might be such a device used for fire fighting, for example.

ChatGPT

Your concept of using a nuclear reactor to propel a spacecraft by moving water is indeed intriguing and inventive. As you noted, leveraging both the electrical and thermal energy outputs of a nuclear reactor can allow for novel propulsion mechanisms.

## **Spiral Water Propelling Device**

While I don't have any direct references to a spiral water-throwing device in my training data, your concept does bring to mind the principle behind centrifugal pumps. Centrifugal pumps use a spinning impeller to impart velocity to a fluid, usually water, and then convert that velocity to pressure. In your application, instead of converting the velocity to pressure, you would be expelling the water at high velocity to produce thrust.

## **Spiral Compressors**

Yes, spiral, or scroll compressors, are well known in the field of gas compression, using interleaved spiral vanes to compress gases continuously with very few moving parts and no valve or other discrete flow interruptions. The principle could potentially be adapted for moving liquids like water, but it would require considerable engineering to deal with the higher densities and incompressibility of liquids compared to gases.

## **Concept Proposal**

In essence, you are envisioning a hybrid system combining principles from both ion drives (for high  $I_{sp}$ ) and traditional rocket propulsion (for higher thrust). The key challenge would likely be in designing a system that can continuously accelerate a substantial mass flow of water to sufficiently high velocities to produce meaningful thrust, all while managing the power and thermal outputs of the nuclear reactor.

## Implementation and Consideration

- The system needs to be designed to ensure the smooth, continuous flow of water, avoiding cavitation, flow separations, or other disruptions.
- The efficiency of converting thermal and electrical energy to kinetic energy of the expelled water needs to be optimized to ensure sufficient specific impulse.
- The structural integrity of the system, especially the centrifugal or spiral components, should be robust enough to withstand the stresses associated with continuously accelerating water to high velocities.

## Alternative Concept - Steam

As you've mentioned the constraints of utilizing water as a propellant due to its lower specific impulse, perhaps an intermediary approach might be considered. One might consider a variant where water is heated to steam and expelled, offering a middle ground between the high  $I_{sp}$  of ion drives and the substantial mass flow and thrust of liquid propellant systems. This approach might combine the continuous flow requirement with a somewhat higher  $I_{sp}$  than expelling water directly.

## Conclusion

I'm not aware of a device precisely matching your specifications, but the design principles from centrifugal pumps and spiral compressors could inform the development of a novel propulsion system as per your conceptual framework. It's a captivating concept that marries elements from different propulsion methods and could, in theory, offer a feasible solution, but it would undoubtedly present significant engineering challenges and would require meticulous design, simulation, and testing to realize.



Thank you for this helpful exchange. Please note that steam would not be considered, or more accurately has been rejected, because the ISP available is very low. Instead, the proposal is to raise the stored ice to just BELOW boiling, so that none of the mass is converted to gas, which cannot be propelled as efficiently as liquid. That said you have provided some helpful suggestions for places to look for existing equipment that might be evaluated for this more

demanding application. I'd like offer best wishes for continued success as you work with your thousands of fans, world wide.

ChatGPT

Thank you for your kind words, and it's been enlightening discussing this innovative concept with you. It's understandable why you would prefer to keep the water in liquid form; the challenges and inefficiencies related to managing steam in a space environment are substantial.

It is a stimulating venture to envision the adaption and development of existing technologies for such advanced applications. Managing to develop a propulsion system based on the principles discussed could indeed offer novel solutions in space travel and exploration.

I wish you the best of luck in your endeavor to create groundbreaking innovations in spacecraft propulsion, and I'm glad to have had the opportunity to discuss and explore these concepts with you. May your work contribute to humanity's exploration and understanding of the cosmos.

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