Reaction Wheels: How They Work and Their Role in Spacecraft Propulsion

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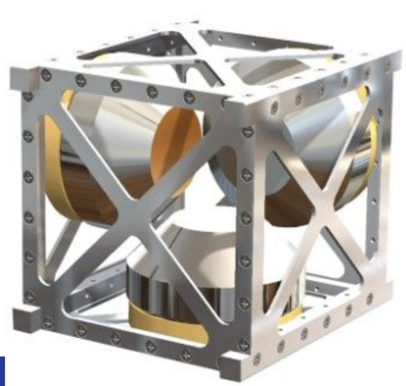
How the System Creates Propulsion

Reaction wheels do not use traditional propulsion like rockets or thrusters but instead rely on the principles of angular momentum to control a spacecraft's orientation. They operate by spinning a flywheel inside the spacecraft, which causes the vehicle to rotate in the opposite direction due to Newton's Third Law (action-reaction principle). By adjusting the speed and direction of the wheel's spin, the spacecraft can change its attitude (orientation) without expelling any mass.



Main Components of the System

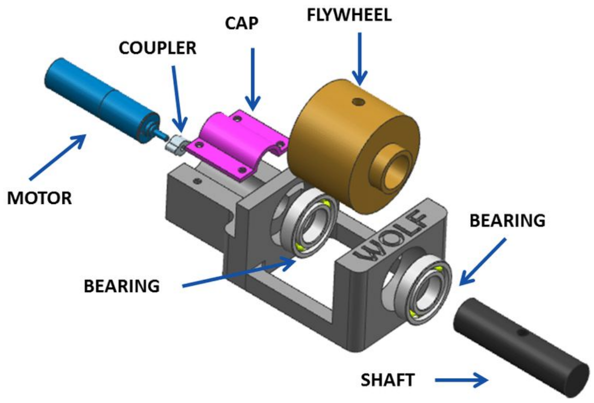
Flywheels – Heavy rotating discs that store angular momentum.

Electric Motors – Used to spin the flywheels at precise speeds.

Control Electronics – Manage the speed and direction of the wheels based on commands.

Gyroscopes and Sensors – Measure the spacecraft's current orientation and provide feedback to the control system.

Power Supply – Provides electrical energy, usually from solar panels or onboard batteries.



Situations Where Reaction Wheels Are the Most Efficient Choice

Long-Term Missions: Reaction wheels are ideal for spacecraft that need precise and sustained attitude control over long durations, such as space telescopes (Hubble, James Webb).

Fuel-Limited Missions: Since they do not consume fuel like thrusters, they are efficient for deep-space probes.

Fine-Tuned Orientation Control: They are used in scientific satellites requiring smooth, gradual movements (e.g., pointing a camera or sensor at a fixed target).

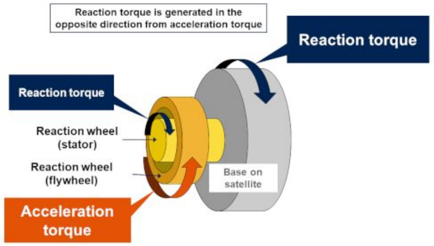
Low-Gravity Environments: Since there is no atmospheric drag, reaction wheels can work efficiently in space without resistance.

Hubble Telescope

Scientific Satellite

How Energy is Converted from Fuel to Propulsion

Reaction wheels do not directly convert fuel into propulsion. Instead, they use electrical energy (often from solar panels or batteries) to power the motors that spin the wheels. The rotation of the wheels creates torque, which reorients the spacecraft. The energy conversion process is:



Electrical energy powers the reaction wheel motors.

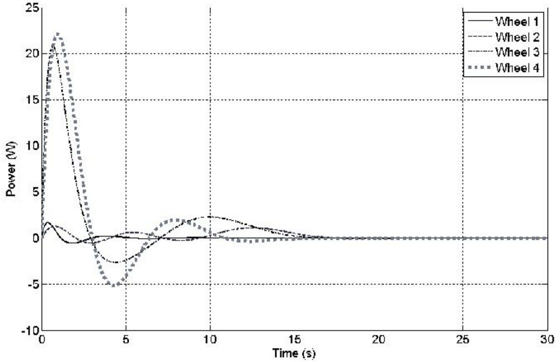
The motors spin the flywheels, storing angular momentum.

The conservation of angular momentum causes the spacecraft to rotate

in the opposite direction.

Fuel Usage for Attitude Adjustments

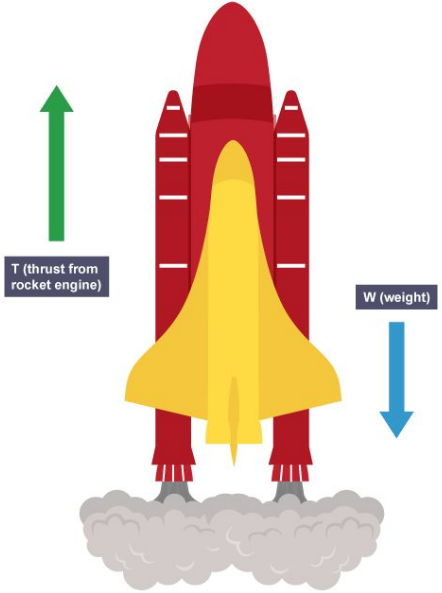
For Reaction Wheels, there are no differences between altitudes due to the box-like shape of it. They only use electricity to manage the rpm, meaning there is no fuel wasted at different altitudes and speeds. This means that it is easier to conserve fuel, and makes long distance treks easier on both weight and cost. The initial boost requires some fuel however, but it averages out as the journey continues.



Fuel Consumption Chart

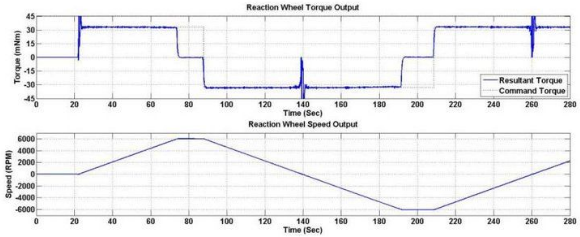
Newton’s Laws

In a reaction wheel the main law being applied is the third law, nicknamed the Action-Reaction law, which states that every action will have an equal and opposite reaction, and in the case of a reaction wheel the spinning of the motor reorients the spacecraft. The torque from that is what propels it, rather than a fluid being launched out like engines using liquid or solid fuel.



Fuel Consumption vs. Speed

For Reaction Wheels, they primarily rely on electrical power, so a higher rpm would drain the batteries faster, while a slower, more consistent pace would conserve electricity. In a case of a craft that uses fuel though, the output power and fuel use is proportional to its fuel, so using fuel quickly leads to more power, but similar to a reaction wheel using it slower would make the fuel last longer.



Reaction wheel speed

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