Pulse detonation engine

A pulse detonation engine, or "PDE", is a type of propulsion system that utilizes detonation waves to combust the fuel and oxidizer mixture. The engine is pulsed because the mixture must be renewed in the combustion chamber between each detonation wave initiated by an ignition source. Theoretically, a PDE can operate from subsonic up to a hypersonic flight speed of roughly Mach 5. An ideal PDE design can have a thermodynamic efficiency higher than other designs like turbojets and turbofans because a detonation wave rapidly compresses the mixture and adds heat at constant volume. Consequently, moving parts like compressor spools are not necessarily required in the engine, which could significantly reduce overall weight and cost. PDEs have been considered for propulsion for over 70 years. Key issues for further development include fast and efficient mixing of the fuel and oxidizer, the prevention of autoignition, and integration with an inlet and nozzle.

To date, no practical PDE has been put into production, but several testbed engines have been built and one was successfully integrated into a low-speed demonstration aircraft that flew in sustained PDE powered flight in 2008. In June 2008, the Defense Advanced Research Projects Agency (DARPA) unveiled Blackswift which was intended to use this technology to reach speeds of up to Mach 6. However the project was cancelled soon afterward, in October 2008.

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Concept

All regular jet engines and most rocket engines operate on the deflagration of fuel, that is, the rapid but subsonic combustion of fuel. The pulse detonation engine is a concept currently in active development to create a jet engine that operates on the supersonic detonation of fuel.

The basic operation of the PDE is similar to that of the pulse jet engine; air is mixed with fuel to create a flammable mixture that is then ignited. The resulting combustion greatly increases the pressure of the mixture to approximately 100 atmospheres (10 MPa), which then expands through a nozzle for thrust. To ensure that the mixture exits to the rear, thereby pushing the aircraft forward, a series of shutters are used to close off the front of the engine. Careful tuning of the inlet ensures the shutters close at the right time to force the air to travel in one direction only through the engine.

The main difference between a PDE and a traditional pulsejet is that the mixture does not undergo subsonic combustion but instead, supersonic detonation. In the PDE, the oxygen and fuel combination process is supersonic, effectively an explosion instead of burning. The other difference is that the shutters are replaced by more sophisticated valves. In some PDE designs from General Electric, the shutters are eliminated through careful timing, using the pressure differences between the different areas of the engine to ensure the "shot" is ejected rearward.

The main side effect of the change in cycle is that the PDE is considerably more efficient. In the pulsejet the combustion pushes a considerable amount of the fuel/air mix (the charge) out the rear of the engine before it has had a chance to burn (thus the trail of flame seen on the V-1 flying bomb). Even while inside the engine the mixture's volume is continually changing, which is an inefficient way to burn fuel. In contrast the PDE deliberately uses a high-speed combustion process that burns all of the charge while it is still inside the engine at a constant volume.
This is said to increase the amount of heat produced per unit of fuel above any other engines, although conversion of that energy into thrust would remain inefficient. A combustion process able to produce more per unit of fuel would, of course, be incredibly valuable in countless applications. Another side effect, not yet demonstrated in practical use, is the cycle time. A traditional pulsejet tops out at about 250 pulses per second due to the cycle time of the mechanical shutters, but the aim of the PDE is thousands of pulses per second, so fast that it is basically continual from an engineering perspective. This should help smooth out the otherwise highly vibrational pulsejet engine – many small pulses will create less volume than a smaller number of larger pulses for the same net thrust. Unfortunately, detonations are many times louder than deflagrations.

The major difficulty with a pulse-detonation engine is starting the detonation. While it is possible to start a detonation directly with a large spark, the amount of energy input is very large and is not practical for an engine. The typical solution is to use a deflagration-to-detonation transition (DDT)—that is, start a high-energy deflagration, and have it accelerate down a tube to the point where it becomes fast enough to become a detonation. Alternatively the detonation can be sent around a circle and valves ensure that only the highest peak power can leak into exhaust.

This process is far more complicated than it sounds, due to the resistance the advancing wavefront encounters (similar to wave drag). DDTs occur far more readily if there are obstacles in the tube. The most widely used is the "Shchelkin spiral", which is designed to create the most useful eddies with the least resistance to the moving fuel/air/exhaust mixture. The eddies lead to the flame separating into multiple fronts, some of which go backwards and collide with other fronts, and then accelerate into fronts ahead of them.

The behavior is difficult to model and to predict, and research is ongoing. As with conventional pulsejets, there are two main types of designs: valved and valveless. Designs with valves encounter the same difficult-to-resolve wear issues encountered with their pulsejet equivalents. Valveless designs typically rely on abnormalities in the air flow to ensure a one-way flow, and are very hard to achieve a regular DDT in.

NASA maintains a research program on the PDE, which is aimed at high-speed, about Mach 5, civilian transport systems. However most PDE research is military in nature, as the engine could be used to develop a new generation of high-speed, long-range reconnaissance aircraft that would fly high enough to be out of range of any current anti-aircraft defenses, while offering range considerably greater than the SR-71, which required a massive tanker support fleet to use in operation.

While most research is on the high speed regime, newer designs with much higher pulse rates in the hundreds of thousands appear to work well even at subsonic speeds. Whereas traditional engine designs always include tradeoffs that limit them to a "best speed" range, the PDE appears to outperform them at all speeds. Both Pratt & Whitney and General Electric now have active PDE research programs in an attempt to commercialize the designs.

Key difficulties in pulse detonation engines are achieving DDT without requiring a tube long enough to make it impractical and drag-imposing on the aircraft; reducing the noise (often described as sounding like a jackhammer); and damping the severe vibration caused by the operation of the engine.

**First PDE powered flight**

The first flight of an aircraft powered by a pulse detonation engine took place at the Mojave Air & Space Port on January 31, 2008. The project was developed by the Air Force Research Laboratory and Innovative Scientific Solutions, Inc (http://www.innssi.com). The aircraft selected for the flight was a heavily modified Scaled Composites Long-EZ, named Borealis. The engine consisted of four tubes producing pulse detonations at a frequency of 80 Hz, creating up to 200 pounds of thrust (890 newtons). Many fuels were considered and tested by the engine developers in recent years, but a refined octane frame without experiencing structural problems from the 195-200 dB detonation waves. No more flights are planned for the modified Long-EZ, but the success is likely to fuel more funding for PDE research. The aircraft itself has been moved to the National Museum of the United States Air Force for display.

**Pulse detonation wave engine**

The pulse detonation wave engine or pulsed detonation wave engine is the same thing or similar. According to rumour it is or was being used in the Aurora aircraft that was created/operates from/designed at "Area 51" in...
Nevada, USA. The pulse detonation wave engine works by detonating a fuel in a special chamber at supersonic speeds. While the aircraft is traveling at that kind of speed, a thrust wall is created at the front of the aircraft. When the fuel is detonated in the chamber, it pushes the thrust wall slightly forward. Repeated detonations cause the aircraft to move at high speeds and also forms the characteristic "donuts on a rope" contrail that has been cited as evidence of the Aurora. See http://www.abovetopsecret.com/pages/pdwe.html for more information.

Popular culture

- In the sci-fi novel Aelita (1923), two Russians travel to Mars in a pulse detonation rocket utilizing "a fine powder of unusual explosive force" (p. 19).
- In the drama television series JAG, the Season Nine episode "The One That Got Away" (original air date October 17, 2003) features the Aurora — which, in the show is a super-secret hypersonic aircraft under development by the CIA, that uses a pulse-detonation engine.
- In the movie Stealth (2005), the advanced fighters use pulse-detonation engines with scramjet boosters.
- The PDE has been used as a story point in a number of modern novels such as Dan Brown's thriller, Deception Point (the second page of the book states that all technologies in the story are non-fictional and exist, albeit without referencing any sources), and Victor Koman's science fiction polemic, Kings of the High Frontier.
- In X-COM, the Interceptor is equipped with a PDE, however even this huge propulsion force is inferior compared to the alien Gravity Wave Engines.

References

3. ^ Hoffmann, N., Reaction Propulsion by Intermittent Detonative Combustion, German Ministry of Supply, Volkenrode Translation, 1940.
5. ^ Pulse Detonation Engines (interview) An interview with Dr John Hoke, head researcher from Innovative Scientific Solutions Incorporated PDE program under contract to the United States Air Force Research Laboratory (http://www.publicadress.net/default,4114.sm) (broadcast on New Zealand radio, 14th April 2007)
7. ^ Borealis display poster text at Museum of USAF

See also

- Scramjet
- Nuclear pulse propulsion

External links

- Innovative Scientific Solutions Inc. (http://www.innssi.com)
- Pulse Detonation Engines (http://www.aardvark.co.nz/pjet/pde.shtml)
- Popular Science (http://www.popsci.com/popsci/aviationspace/e46d5b4a1db84010vgnvcm1000004eeccbcdcrd.html)
- (Video) The high detonation temperature inside the tube of an experimental PDE causes the seals to heat up and catch fire. (http://www.youtube.com/watch?v=GqLOI3h0DC8)
- (Video) An experimental PDE operating with a detonation frequency of 1 Hz where the pulses are clearly defined. (http://www.youtube.com/watch?v=1BjLx2AvrM)
- (Video) An experimental PDE operating with a detonation frequency of 25 Hz. (http://www.youtube.com/watch?v=yXsslRgRs4)
- 2-D pulse-detonation engine simulation (http://es.youtube.com/watch?v=mSiER26ZHBg)
- Fox News report on the Blackswift (http://www.foxnews.com/video/index.html?playerId=videolandpage&streamingFormat=FLASH&referralObject=1791927&referralPlaylistId=e059f7416cd3e6a978256d927c7bb152d9988581)
DARPA May 2009 notes on PDE

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