Atmospheric Vortex Engine Prototype

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Abstract

The paper describes an experimental program carried out on two small scale atmospheric vortex engine (AVE) outdoor prototypes. An AVE would use a controlled tornado-like vortex to harness the energy produced when heat is carried upward by convection in the atmosphere. The implications of the experimental results for future development steps are discussed.

The AVE is an energy alternative with enormous potential; it will produce atmospheric vortices and harness their energy. Transporting a small part of the heat stored in tropical oceans upward to the upper troposphere could provide abundant clean power. Nature produces vortices in a wide range of sizes. There are several ways tornado like vortices could be produced and controlled.

Introduction

An atmospheric vortex engine (AVE) uses a controlled tornado-like vortex to harness the energy produced when heat is carried upward by convection in the atmosphere. The vortex is produced by admitting warm air tangentially at the base of a circular station. The energy is captured with turbines located at grade. Vortex engines could alleviate global warming by reducing fossil fuel consumption and by hastening upward heat flow. The AVE would harness the process responsible for the energy of tornadoes and hurricanes. The process could become a major source of clean energy and could provide other benefits such as precipitation and cooling.

The proposed AVE has been described in engineering journals and magazines [1-4]. The thermodynamic basis of the AVE has been documented in atmospheric science journals: [5-7] and is consistent with atmospheric science [8-10].

This paper describes an experimental program carried out on two small scale prototypes. Details of the proposal and of its thermodynamic basis previously described in the above reference are not repeated in this paper. Implications of the experimental results for future development steps are discussed.

Experimental Results

The project comprised two prototypes; an enclosed 6 m high prototype and an unenclosed 3 m high prototype. The testing program took place at Lambton College in Sarnia, Ontario from 2013 to 2015. Financial support for the project was provided by Breakout Labs and by the National Science and Engineering Council of Canada (NSERC).The project demonstrated the possibility of producing vortices extending up 40 m in the free atmosphere from low temperature heat source under appropriate atmospheric conditions.

Enclosed prototype

The 9 m diameter by 6 m high enclosed prototype located at the College main campus produced 25 cm diameter vortices extending up to 40 m beyond the top of the prototype. The air was heated by 30 to 50 ℃ with propane air heaters located in the 1.5 m high lower chamber, entered the periphery of the 1.2 m high upper chamber tangentially and exited via a central roof opening and a 1.8 m diameter by 3 m high transparent cylinder. Fig 1, 2 and 3 show: the prototype, a vortex made visible with black smoke and a cross section of the prototype. Photos and videos of vortices are available at: http://vortexengine.ca/Physical_Models_LM-9.shtml

The air heaters were direct fired propane construction heaters called salamanders. The heaters were located in the lower chamber rather than the air inlets to avoid pushing air into the prototype. There was no motor or mechanical energy input. The only driving force was the buoyancy of the rising warm air.

Heat input and the air flow were typically 100 kW and 2.8 kg/s respectively. Vortices 50 cm in diameter could be produced consistently within the transparent plastic cylinder. Vortices extending beyond the top to cylinder could only be produced at winds of less than 1 m/s. Slight wind was sufficient to push the smoke sideways at the top of the cylinder and to destroy the vortex. Producing vortices extending high in the atmosphere with a small prototype was a challenge and could only be achieved occasionally.

On the occasions when the vortex extended beyond the top of the cylinder, the diameter of the vortex in the cylinder appeared to shrink from about 50 to about 25 cm as extension developed. This shrinkage was interpreted as an indication that the air rising in the lower part of the vortex was drawn up by the buoyancy of the air in the upper part of the vortex.

The prototype had: 10 temperature probes, 3 air velocity sensors, 2 hot wire anemometers, 1 propeller anemometer, many tell tale flow indicators, 2 humidity sensors, 1 fuel flow transmitters, 1 pressure transmitter two low velocity wind socks and a weather station. Data was collected continuously with a state of the art industrial data acquisition system. Vertical velocities in the vortex were estimated at 1 to 3 m/s. Horizontal velocities of up to 12 m/s were measured near the base of the vortex. The heat input from the three salamanders and the opening of the eight air inlet doors were adjustable. The maximum available heat input was 260 kW.

Fig. 1 Enclosed prototype

Fig. 2 Enclosed prototype vortex made visible with black smoke emitter

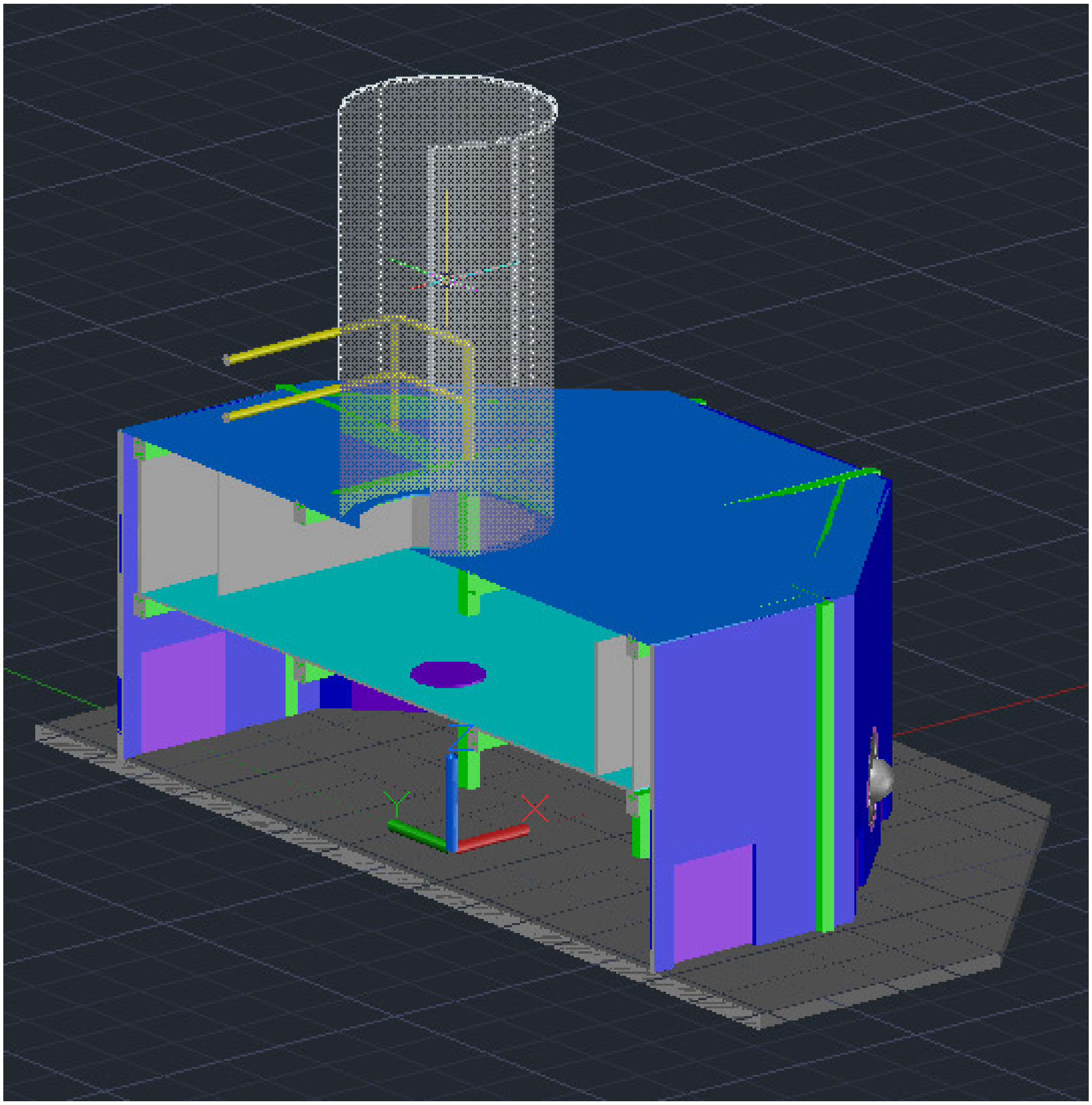

Fig. 3 Enclosed prototype cross section

Vortex visualization techniques were developed. Smoke was injected in the center of the vortex to make it visible. A 10 cm diameter pipe was provided to draw smoke from smoke emitters into the vortex. Vortex visualization was an important documentation tool. The vortices were only visible for the 2 minutes duration of the smoke emitters but must have been present for longer duration and more frequently than observed. The production of vortices was enhanced by the use an additional circular 20 kW propane heater located in the center and on the floor of the upper chamber. The vortex was too small to drive a turbine but was capable of driving propeller type anemometer or a pinwheel. Pressure reductions of up to 10 Pa were measured at the base of the vortex. The fact that smoke was drawn in the center of the vortex showed that pressure reduction was produced. The power produced by the small vortex was calculated to be in order of 10 W.

The prototype demonstrated that vortices can be produced from low temperature heat. The prototype has been a valuable learning environment and has provided the basis for the design of larger AVE's. The temperature of the air rising in the vortex was typically 60 °C. The size of the vortices produced by the enclosed prototype may have been limited by the diameter of the roof opening relative to diameter at the deflectors circle or by the convoluted air path of the two chambers arrangement. Many configuration and modes of operation were tested. Ambient conditions had more effect of the vortex than the mode of operation making for arduous testing. Changing the diameter of the deflector circle was not practical on the enclosed prototype.

Unenclosed Prototype

As a result of the enclosed prototype findings, an unenclosed prototype, intended to provide less interference with the flow and more flexibility, was built at the Lambton College fire school. The fire school was an appropriate location since producing fires and smoke are integral to its function. The deflectors consisted of potable fence sections covered with aluminum siding. The warm air was provided by four 90 kW indirect diesel fired air heaters. The temperature of the air at the outlet of the heaters was typically 50 to 65 °C. Total heat available from the heaters was usually in the 200 to 300 kW range. The heat input to the vortex may have been considerably lower because only part of the warm air from the heaters entered the vortex.

The unenclosed prototype produced vortices up to 50 cm in diameter by 80 m high. The unenclosed prototype produced vortices more consistently than the enclosed one. It was almost always possible to produce vortices when the wind was under 1 m/s and once established the vortices were able to sustain winds of up to 2 m/s. Some of the vortices lasted over 10 minutes. Fig 4 shows the unenclosed prototype. Photos and videos of the unenclosed prototype can be seen at: http://vortexengine.ca/Physical_Models_LFS.shtml

Implication for future development

Small vortices are easily disturbed by wind and turbulence. An earlier 1 m diameter garage indoor prototype produced 5 cm diameter vortices extending up to 2 m high. The vortex was so sensitive to turbulence that closing the garage door a few minutes prior to a test helped make the vortex more stable and vertical. Small scale prototypes have demonstrated that it is possible to produce vortices from low temperature heat but producing long lasting vortices will require much larger installations.

The ability to resist being disturbed by wind and atmospheric turbulence increases with vortex size. For any atmospheric condition there is a minimum AVE size. Minimum size increases with wind and turbulence. In the prototypes, increasing size and heat input produced a slight increase in vortex size and a more significant increase in how frequently vortices could be produced. Based of Lambton test results, the minimum size for a commercially viable AVE could be a heat input of 40 MW(t), a vortex 5 m in diameter, and an AVE 20 m in diameter.

Specific works is the work per unit mass of raised air. Ideal specific work equals the reduction in the enthalpy of the raised air minus the increase in its potential energy. The ideal specific work for the Lambton enclosed prototype and for hurricanes are roughly 10 and 4000 J/kg respectively corresponding to velocities of 7 and 90 m/s. Ideal velocity is equal to the square root of twice the specific work. Actual specific work could be up to 80 % of ideal specific work because friction losses in vortex flow are low.

Fig. 4 Unenclosed Prototype – Vortex made visible with white smoke emitter

Raising 24 °C saturated surface air can produce a specific work of 3400 J/kg corresponding to force 5 hurricane winds of 82 m/s. Saturated air at 24 °C can be produced by spraying ambient air with 26 to 30 °C sea water. Ideal work increases from zero for saturated air at 22.6 °C to 7000 J/kg for saturated air at 26 °C. Increasing either the temperature or the relative humidity of the air both increase specific work. Raising 32 °C air with 50 % relative can produce about the same specific work as raising 24 °C saturated air. The above numbers are based on raising the air to its equilibrium level which in the tropics is typically located at a pressure of 15 kPa corresponding to an elevation of 14.2 km. Specific work can be small up to a certain level and then increases rapidly. In the 24 °C saturated air case, raising air to the 43 kPa level which has an elevation of 7 km could only produce 100 J/kg; the work produced in the first three kilometres can be zero. Most of the work is produced as the air is raised from the 7 to the 14 km level. Sensible heat addition starts work production at lower elevation than latent heat addition. Fortunately the work is transmitted downward and can be captured by turbines located at grade.

The fact that the specific work is mostly produced in the upper part of the vortex explains why atmospheric vortices are so rare in spite of the fact that the heat content of surface air is more than enough to support established vortices. Starting a vortex requires a disturbance such as a local hot spot, an updraft or convergence. Hurricanes are rare in spite of the fact that tropical waters are usually warm enough to produce specific work of over 4000 J/kg. When there is a tornado in Oklahoma the surface air is likely warm enough to produce tornadoes in the in the surrounding states.

The power output of large AVE's increases exponentially with size. Power output is equal to specific work times flow. Flow is proportional to the square of vortex diameter and to average upward velocity. A 50 m diameter vortex could have an upward air flow of 70,000 kg/s and produce 200 MW of electrical energy.

Sea water at 26 to 30 °C is the heat source that power hurricanes. The heat source for hurricane Sandy was warm sea water. AVE's could produce carbon free energy from natural heat sources such as warm sea water but the ideal heat source for process development is waste heat from industrial processes such as thermal power stations. The low temperature waste heat is already concentrated in one location and utilities spend money getting rid of it. An AVE could increase the output of a thermal power station by converting 15 % of its waste heat to electricity without additional fuel consumption. Alternatively the same power could be produced with 15 % less fuel. The ideal candidate for the next development stage would be a mid size (50 MWe) gas turbine power plant. Gas turbine flue gas is a good development candidate because the flue gas is already warm and there is no need for heat exchangers. The next development stage could be to replace the cooling tower of a 200 MWe steam power plant with an AVE which could have wet or dry heat exchangers.

Conclusion

There is an urgent need to stop global warming; there is no hope of doing so without a cheap, carbon free and abundant energy alternative because humanity will not accept drastic cuts in energy availability. The energy produced in hurricane Sandy was more than the energy produced by humans in a year. The power produced by large tornadoes can exceed the power output of a large power station. There is no physical reason why the atmospheric energy production process could not be controlled. Mother Nature does it why can't we?

The AVE is an energy alternative with enormous potential; it will produce atmospheric vortices and harness their energy. Atmospheric upward heat convection could provide abundant carbon free energy. Transporting a small part of the heat stored in tropical oceans upward to the upper troposphere could provide abundant clean power. There are many low temperature heat sources at hand such as warm humid air and waste heat.

Nature produces vortices in a wide range of sizes: dust devils, water spouts, tornadoes, fire whirls and hurricanes. There are many ways tornado like vortices could be produced and controlled to produce energy and other benefits. We are not doomed to become extinct from global warming – there is hope.

References

1. Michaud, L.M., “Vortex process for capturing mechanical energy during upward heat-convection in the atmosphere.” *Applied Energy,* No. 62, pp. 241-251, 1999.

2. Michaud, L. and Michaud, E., “Harnessing energy from upward heat convection.” *Power Magazine*, Vol. 154, No. 3, pp. 78-81, 2010.

3. Michaud, L. and Renno N,. “The sky`s the limit.” *American Society of Mechanical Engineering Magazine,* Vol. 133, No. 4, pp 42-44, 2011.

4. Nizetic, S., “Analytical approach for estimating the pressure drop potential in convective vortex heat engines.” *Transactions of the Canadian Society for Mechanical Engineering*. Vol 38, No. 1, pp. 81-91, 2014.

5. Michaud, L.M., “Thermodynamic cycle of the atmospheric upward heat convection process.” *Meterology and Atmospheric Physics*. Vol. 72, pp. 29-46, 2000.

6. Michaud, L.M,, “Total energy equation method for calculating hurricane intensity.” *Meterology and Atmospheric Physics*. Vol. 78, pp. 35-43, 2001.

7. Michaud, L.M., “On hurricane energy.” Meteorology and Atmospheric Physics. Vol 118, no. 1, pp. 21-29, 2012.

8. Emanuel, K.A., “An air-sea interaction theory for tropical cyclones. Part I: Steady-state maintenance.” *Journal of the Atmospheric Sciences*. Vol. 43, No. 6, pp. 585-604, 1986.

9. Holland, G.J., “The maximum potential intensity of tropical cyclones.” *Journal of the Atmospheric Sciences*. Vol. 54, No. 21, pp. 2519-2541, 1997.

10. Renno, N.O., “A thermodynamically general theory for convective vortices.” *Tellus*, Vol. 60A, pp. 688-699, 2008.