Software Sphere

Power generator based on atmospheric pressure and gravity

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Abstract

In this article I show a relatively simple system that can provide a net power that comes from the atmospheric pressure. The system uses the pressure of a water column, and two other external devices to create a cycle that has a net power output. The potential use of such system is probably limited by many technical factors, but the system serves as an example of how power can be extracted continuously from the atmosphere.

1 Description

Let's consider an horizontal cylinder with a piston that can run into it without friction. The cylinder is surrounded by air at the atmospheric pressure. The right section of the cylinder contains initially air at the atmospheric pressure and temperature. The left section instead is filled with water coming from a big reservoir placed at a greater height respect to the median line of the cylinder. When the piston is left to go the water pressure pushes it towards right and the air in the cylinder gets compressed. The piston accelerates but after reaching a maximum speed it starts to decelerate and eventually stops. At this point the air has the maximum compression. Let's suppose that the piston now is anchored to something that keeps it at this position, and that a valve on the right section of the cylinder is opened. The compressed air can exit and expand doing some work on an external device. When the expansion has finished we close this valve, and open another valve that lets the external air enter into the cylinder, with atmospheric pressure. The cylinder now has atmospheric pressure inside, then we can push the piston towards left and bring it to the initial position, pumping the water back into the tank, and this requires a work from the motor. When the piston has returned to its initial position we have completed a cycle, and in this cycle there has been work done by the compressed air to another device, and work done by our motor to push the piston back. If the work done by the air is greater than the work done by the motor we have obtained a net work towards another device, or a net energy.

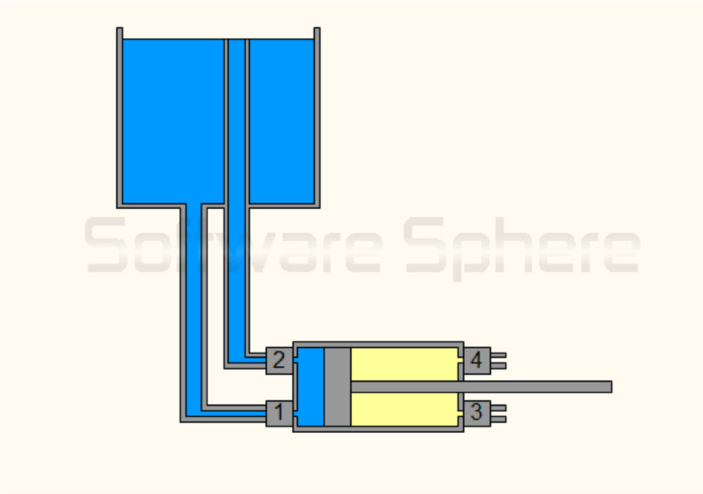

Figure 1:Basic system

2 Active phase

The active phase starts with the right face of the piston at distance b respect to the right internal wall of the cylinder. Valves 2, 3 and 4 are closed and valve 1 is open. Let A be the area of the piston. More precisely the area of the right face is a bit smaller than A because of the piston's shaft, but in this analysis we neglect this. The initial volume of the air inside the cylinder is $V_0 = Ab$. The initial air pressure is equal to the atmospheric pressure p_0. We suppose that the pressure of the water in the cylinder is constant and equal to $p_c = p_0 + p_1$ where $p_1 = \rho g H$ is the hydrostatic pressure. Let p be the pressure of the air in the compression chamber. Taking the x axis directed towards right, with the origin at the initial position of the piston, the equation of the motion of the piston during the active phase is:

$$m\ddot{x} = (p_c - p)A \tag{1}$$

or:

$$m\ddot{x} + pA = F_a \tag{2}$$

with:

$$F_a = (p_0 + p_1)A \tag{3}$$

Here we suppose that F_a is constant. A more detailed analysis would consider also the motion of the water inside the cylinder but in this first analysis we just suppose that the water pushes with constant pressure. By multiplying the equation by the speed $\dot{x}$ and integrating between the initial time and the time t we have:

$$\int_0^t m\dot{x}\ddot{x}d\tau + \int_0^t Ap\dot{x}d\tau = F_a \int_0^t \dot{x}d\tau \tag{4}$$

The second integral is the work done on the air:

$$\int_0^t Ap\dot{x}d\tau = \int_{V_0}^{V_t} pdV = w_a(t) \tag{5}$$

and with the initial conditions $x(0) = 0$ and $\dot{x}(0) = 0$:

$$\frac{1}{2}mv^2 + w_a(t) = F_a x \tag{6}$$

At the point x_m of maximum compression the piston's speed is zero so the relation between the work done to compress the air up to the point of maximum compression and the distance traveled by the piston is:

$$W_a = F_a x_m \tag{7}$$

It is convenient to define the dimensionless compression factor:

$$\xi = \frac{x_m}{b} \tag{8}$$

so:

$$W_a = F_a b \xi \tag{9}$$

or:

$$W_a = (p_0 + p_1)Ab\xi = (p_0 + p_1)V_0\xi \tag{10}$$

3 Air energy

When the internal air is compressed its internal energy increases. If the cylinder does not remove any heat from the compressed air then the internal energy of the air increases of the amount W_a. When the air is left free to expand and return to the atmospheric pressure it will do a work equal to this. If there are heat losses the internal energy increases less than this, so when the air expands it will do a smaller work, but during the expansion the air could also reabsorb the heat from the surroundings and so its work could increase.

4 Push phase

After the air has exited the input valve 3 can be opened and other air enters into the chamber, bringing the air pressure to the right of the piston to the atmospheric value. Now we can push the piston using an external force F_e to bring the piston back to the initial position. The equation for the push phase is:

$$m\ddot{x} = F_a - F_e - p_0 A \tag{11}$$

or:

$$m\ddot{x} = p_1 A - F_e \tag{12}$$

The atmospheric pressure inside the cylinder cancels the atmospheric pressure that pushes on the free surface of the water in the tank. The external force F_e created by the motor does not need to be constant, actually it has to vary during the push phase in such a way that the piston arrives to the initial position with zero speed. Anyway we can calculate the work done by the motor in the push phase. For this let's take the time origin at the beginning of the push phase. Let t_p be the duration of the push phase, i.e. the time required to bring the piston back at $x = 0$. Multiply the equation by the speed $\dot{x}$ and integrate from $t = 0$ to $t = t_p$:

$$\int_0^{t_p} m\dot{x}\ddot{x}d\tau = \int_0^{t_p} p_1 A\dot{x}d\tau - \int_0^{t_p} F_e\dot{x}d\tau \tag{13}$$

the last integral is the work done by the motor in the push phase, consider that $F_e > 0$ and $\dot{x} < 0$:

$$W_p = -\int_0^{t_p} F_e\dot{x}d\tau > 0 \tag{14}$$

so with the conditions $x(0) = x_m$, $x(t_p) = 0$ and $\dot{x}(0) = 0$:

$$\frac{1}{2}mv(t_p)^2 = -p_1 Ax_m + W_p \tag{15}$$

but at the instant t_p the piston must stop again and so:

$$W_p = p_1 Ax_m \tag{16}$$

or:

$$W_p = p_1 V_0 \xi \tag{17}$$

5 Energy balance

At the end of a cycle then the piston has returned to its original position, inside the chamber there is again air at pressure p_0 and volume V_0, the machine has taken a work W_p from the motor and the compressed air has delivered a work W_a to the external device, and W_a is greater than W_p, the difference is:

$$W_n = W_a - W_p = p_0 V_0 \xi \tag{18}$$

This is exactly the work done by the external air on the piston during the push phase, so we can say that the net energy of the cycle comes from the atmosphere.

Since $W_a > W_p$ in theory we could use the energy W_a to power the motor, and we still would have a net energy W_n available for other devices, which means that this system is a generator of free energy. In practice there would be energy losses due to the temperature rise, and the conversion of the compressed air into electric energy, but at least in theory there should be some energy left.

The power instead depends on the duration of the cycle. The duration of the active phase cannot be expressed in closed form so it has to be calculated numerically, and it depends on the mass of the piston. The duration of the push phase depends also on the power of the pushing motor.

6 Normalized energies

It is convenient to consider the work and the energy normalized to the energy $p_0 V_0$:

$$y_a = \frac{W_a}{p_0 V_0} = (1+\beta)\xi \tag{19}$$

$$y_p = \frac{W_p}{p_0 V_0} = \beta\xi \tag{20}$$

$$y_n = \frac{W_n}{p_0 V_0} = y_a - y_p = \xi \tag{21}$$

where β is:

$$\beta = \frac{p_1}{p_0} = \frac{\rho g H}{p_0} \tag{22}$$

7 Adiabatic case

In the adiabatic case the pressure of the internal air is related to the volume of the air by:

$$pV^\gamma = p_0 V_0^\gamma \tag{23}$$

where $\gamma = 1.4$ for air, so the pressure is given by:

$$p = \frac{p_0}{(1-\xi)^\gamma} \tag{24}$$

Inserting this in the integral that gives the work done on the air we find at last:

$$W_a = \frac{p_0 V_0}{\gamma - 1}\left[\frac{1}{(1-\xi)^{\gamma-1}} - 1\right] \tag{25}$$

Then the equation that determines the point of maximum compression becomes:

$$\frac{1}{(1-\xi)^{\gamma-1}} - 1 = (1+\beta)(\gamma-1)\xi \tag{26}$$

It easy to see that this equation has always a solution greater than 0 for every $\beta > 0$. Considering the left side as a function:

$$f(\xi) = \frac{1}{(1-\xi)^{\gamma-1}} - 1 \tag{27}$$

then:

$$f'(\xi) = (\gamma-1)(1-\xi)^{-\gamma} \tag{28}$$

$$f'(0) = \gamma - 1 \tag{29}$$

so the straight line $(1+\beta)(\gamma-1)\xi$ is always above the curve, as long as $\beta > 0$.

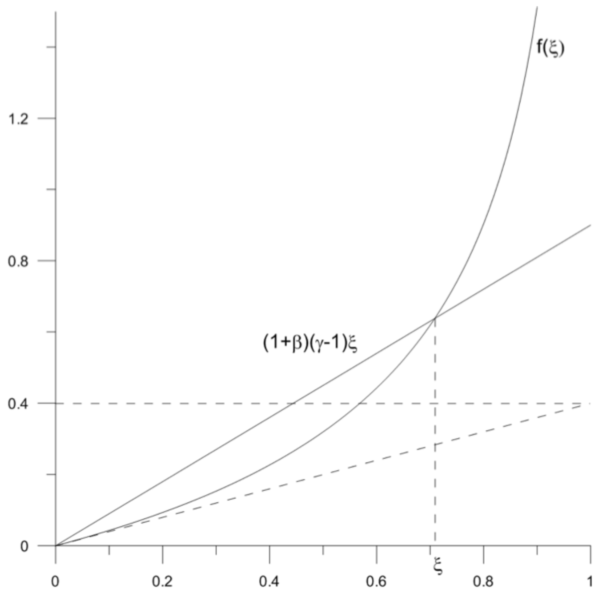

Figure 2:Intersection that determines the compression factor

This equation cannot be solved in closed form but its solution can be calculated numerically, for example with the Newton's method.

The final temperature of the compressed air in the adiabatic case is given by:

$$T_m = \frac{T_f}{T_0} = \frac{1}{(1-\xi)^{\gamma-1}} \tag{30}$$

The following table gives the normalized energies, final pressure and temperature and the ratio $\eta = y_a / y_p$ for several values of β in the adiabatic hypothesis:

β	ξ	y_a	y_p	y_n	η	p_m	T_m
0.1	0.13	0.14	0.01	0.13	11.00	1.21	1.06
0.2	0.23	0.28	0.05	0.23	6.00	1.45	1.11
0.3	0.32	0.41	0.10	0.32	4.33	1.71	1.17
0.4	0.39	0.55	0.16	0.39	3.50	2.00	1.22
0.5	0.45	0.67	0.22	0.45	3.00	2.31	1.27
0.6	0.50	0.80	0.30	0.50	2.67	2.65	1.32
0.7	0.55	0.93	0.38	0.55	2.43	3.02	1.37
0.8	0.58	1.05	0.47	0.59	2.25	3.42	1.42
0.9	0.62	1.18	0.56	0.62	2.11	3.85	1.47
1.0	0.65	1.30	0.65	0.65	2.00	4.32	1.52
1.1	0.67	1.42	0.74	0.67	1.91	4.81	1.57
1.2	0.70	1.54	0.84	0.70	1.83	5.34	1.61
1.3	0.72	1.65	0.93	0.72	1.77	5.91	1.66
1.4	0.74	1.77	1.03	0.74	1.71	6.52	1.71
1.5	0.76	1.89	1.13	0.76	1.67	7.19	1.76
1.6	0.77	2.01	1.23	0.77	1.63	7.86	1.80
1.7	0.78	2.12	1.33	0.79	1.59	8.58	1.85

1.8	0.80	2.23	1.44	0.80	1.56	9.34	1.89
1.9	0.81	2.35	1.54	0.81	1.53	10.15	1.94
2.0	0.82	2.46	1.64	0.82	1.50	11.00	1.98
2.1	0.83	2.57	1.74	0.83	1.48	11.89	2.03
2.2	0.84	2.68	1.84	0.84	1.45	12.83	2.07
2.3	0.85	2.79	1.95	0.85	1.43	13.82	2.12
2.4	0.85	2.91	2.05	0.85	1.42	14.87	2.16
2.5	0.86	3.02	2.15	0.86	1.40	15.96	2.21
2.6	0.87	3.14	2.26	0.88	1.39	17.27	2.26
2.7	0.88	3.25	2.36	0.89	1.37	18.45	2.30
2.8	0.88	3.36	2.47	0.89	1.36	19.68	2.34
2.9	0.89	3.46	2.57	0.89	1.35	20.97	2.39
3.0	0.89	3.57	2.67	0.90	1.34	22.32	2.43
3.1	0.90	3.68	2.78	0.90	1.32	23.73	2.47
3.2	0.90	3.79	2.88	0.90	1.31	25.20	2.51
3.3	0.90	3.89	2.98	0.91	1.30	26.74	2.56
3.4	0.91	4.00	3.09	0.91	1.30	28.33	2.60
3.5	0.91	4.11	3.19	0.91	1.29	30.00	2.64
3.6	0.92	4.21	3.30	0.92	1.28	31.72	2.69
3.7	0.92	4.32	3.40	0.92	1.27	33.52	2.73
3.8	0.92	4.43	3.50	0.92	1.26	35.39	2.77
3.9	0.92	4.53	3.61	0.93	1.26	37.32	2.81
4.0	0.93	4.64	3.71	0.93	1.25	39.33	2.86
4.1	0.93	4.74	3.81	0.93	1.24	41.41	2.90
4.2	0.93	4.85	3.92	0.93	1.24	43.57	2.94
4.3	0.93	4.96	4.02	0.94	1.23	45.80	2.98
4.4	0.94	5.11	4.13	0.98	1.24	49.14	3.04
4.5	0.94	5.21	4.23	0.98	1.23	51.47	3.08
4.6	0.94	5.31	4.33	0.98	1.23	53.88	3.12
4.7	0.94	5.41	4.44	0.98	1.22	56.37	3.16
4.8	0.95	5.51	4.54	0.97	1.21	58.95	3.21
4.9	0.95	5.61	4.64	0.97	1.21	61.62	3.25
5.0	0.95	5.72	4.74	0.97	1.20	64.38	3.29

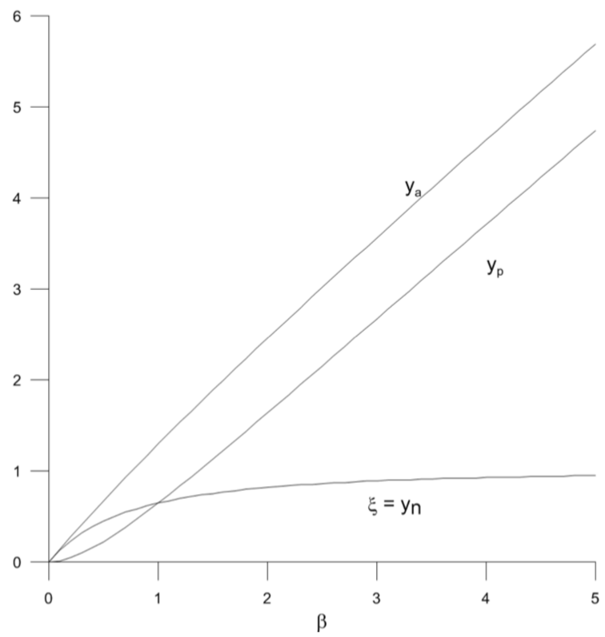

Figure 3:Plot of the normalized energies vs the parameter β

8 Example

For example if $\beta = 2$ the compression, in the adiabatic case, is 0.82, the final pressure is 11 bar, the final absolute temperature is 1.98 times the initial absolute temperature, so supposing that the initial air temperature is 25°C, the final air temperature is:

$$t_f = 1.98 * 298.15 - 273.15 = 317^\circ C \quad (31)$$

If the volume V_0 is 1 m3 then the net energy is:

$$W_n = p_0 V_0 \xi = 101325\ Pa * 1\ m^3 * 0.82 = 83086\ J \quad (32)$$

and so, if the cycle is completed in 2 s the net power would be 41543 W. Of course this value is much larger than the net power of a real system because of the many energy losses. A value of $\beta = 2$ is obtained with an height of water equal to:

$$H = \frac{p_1}{\rho g} = \frac{2 * 101325\ Pa}{1000\ kg/m^3 * 9.81\ m/s^2} = 20.65\ m \quad (33)$$

9 Conclusions

This relatively simple system shows that it is possible, in theory, to extract free energy from the atmosphere with a combination of mechanical, hydraulic and gas dynamic processes, plus a motor that can use the energy provided by the compressed air generated by the system. The practical application depends on the availability of technologies that can convert the compressed air, with a relatively low pressure and speed, into mechanical energy of other type. Ideally the compressed air could be used to spin a turbine connected to an alternator that can generate electric power but the losses must be very small or else the net energy would be lost. The actual power of course would depend on the speed of the piston, especially that of the return phase.

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