The Amin Cycle

Let us consider a system in which a cylinder filled with an ideal gas is rotated. The radius of rotation of the cylinder is constant. The rotational speed of the cylinder can be varied by changing the value of ω (angular speed). The cylinder is equipped with a frictionless, moving piston located on the side closer to the center of the rotation. The piston can compress and expand the volume of the cylinder. The cycle comprises of the following processes (Figure 1):

(1-2) The gas expands isothermally at a temperature T in the cylinder at a constant low speed ω_1.

(2-3) The rotational speed is increased from ω_1 to ω_2 at constant volume and temperature.

(3-4) The gas is compressed isothermally at a temperature T in the cylinder at a constant high speed ω_2.

(4-1) The rotational speed is decreased from ω_2 to ω_1 at constant volume and temperature.

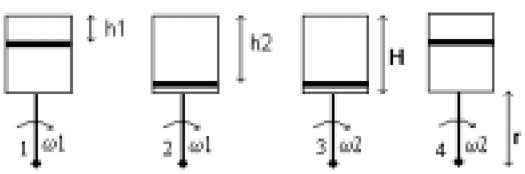

Figure 1

In a rotating cylinder, the molecules of the ideal gas have a distribution according to Boltzmann's distribution Law. The centrifugal acceleration is represented by $a = v^2/r$. However, $v = \omega r$, then $a = \omega^2 r$. Therefor according to Boltzmann's distribution Law, the pressure on the piston surface can be derived using equation 1.

From the first law of thermodynamics:

dQ = dU + dW + dKE.

For an isothermal process, dU = nCvdT = 0.

The work dW = PdV.

$$\frac{dP}{P} = \int_{r+H-h}^{r+H} -\frac{m\omega^2 r}{kT}\,dr \Rightarrow P = P_o e^{-\frac{m\omega^2 r^2}{2kT}}\Big|_{r+H-h}^{r+H}$$

Equation 1

Let us analyze the energies at each step:

KE = $[\tfrac{1}{2}m\omega^2(r+H)^2 - \tfrac{1}{2}m\omega^2(r+H-h)^2]$. For all steps, $\tfrac{1}{2}m\omega^2(r+H)^2$ is constant and cancels out. Thus we shall not rewrite it again.

(1-2) $dQ_{1-2} = nCvdT + P_e dV + \tfrac{1}{2}m(\omega_1)^2\,[(r+H-h_1)^2-(r+H-h_2)^2]$
$= P_e dV + \tfrac{1}{2}m(\omega_1)^2\,[(r+H-h_1)^2-(r+H-h_2)^2]$

(2-3) $dQ_{2-3} = nCvdT + PdV + \tfrac{1}{2}m[(\omega_1)^2-(\omega_2)^2](r+H-h_2)^2$
$= \tfrac{1}{2}m[(\omega_1)^2-(\omega_2)^2](r+H-h_2)^2$

(3-4) $dQ_{3-4} = nCvdT + P_c dV + \tfrac{1}{2}m(\omega_2)^2\,[(r+H-h_2)^2-(r+H-h_1)^2]$
$= P_c dV + \tfrac{1}{2}m(\omega_2)^2\,[(r+H-h_2)^2-(r+H-h_1)^2]$

(4-1) $dQ_{4-1} = nCvdT + PdV + \tfrac{1}{2}m[(\omega_2)^2-(\omega_1)^2](r+H-h_1)^2$
$= \tfrac{1}{2}m[(\omega_2)^2-(\omega_1)^2](r+H-h_1)^2$

According to the definition of a thermodynamic cycle: Net Heat = Net Work

$\mathbf{dQ_{Net}} = dQ_{1-2} + dQ_{2-3} + dQ_{3-4} + dQ_{4-1}$

= $\mathbf{P_e dV + P_c dV}$

$\mathbf{dW_{Net}} = \mathbf{P_e dV + P_c dV}$

Efficiency $\eta = W_{Net} / Q_{1-2} = \mathbf{1 + P_c dV/P_e d}$

$\Rightarrow \mathbf{P_c dV + P_e dV \neq 0}$

$$P_c = P_0 e^{-\frac{m\omega_2^2}{2kT}\left(h_2^2-h_1^2-2(r+H)(h_2-h_1)\right)} \qquad \ldots(2)$$

$$P_e = P_0 e^{-\frac{m\omega_1^2}{2kT}\left(h_1^2-h_2^2-2(r+H)(h_1-h_2)\right)} \qquad \ldots(3)$$

$$P_c dV_{comp} + P_e dV_{\exp} =$$

$$P_0\left(h_2 - h_1\right)\begin{pmatrix} e^{-\frac{m\omega_2^2}{2kT}\left(h_2^2-h_1^2-2(r+H)(h_2-h_1)\right)} - \\ e^{-\frac{m\omega_1^2}{2kT}\left(h_1^2-h_2^2-2(r+H)(h_1-h_2)\right)} \end{pmatrix}$$

$dV_{comp} = h_2 - h_1$ and $dV_{exp} = h_1 - h_2$

In the Amin Cycle, the heat conversion efficiency depends on the magnitude of the acceleration difference only. The cycle gives similar results for different types of accelerations and various combinations of Isothermal, Adiabatic and Polytropic processes.

References:

1. *Feynman,R.,Leighton,R.,Sands,M.,"The Feynman Lectures on Physics: Addison-Wesley Publishing Co., 1989.*
2. *Saad, M, "Thermodynamics – Principles and Practice, Prentice-Hall, Inc., 1997*