THE HYPER-SONIQUE VORTEX RAMJET PROPULSION

Abstract. Apply an artificial spinning vortex in the engine, a new kind of ramjet could be made out to work from M1 to M10 by centrifugal force in theory. This efficient method can provide high quality push power for many types of supersonic vehicles. The compress course has been solved under some simplifies in this article too. Although it is simple, it’s a way to have a look at the result of this special engine until more accurate solution is get.

Keywords: supersonic, vortex, spin, ramjet, engine.
pushing force and the more faster of the air entering, the more efficient it can works well!

Like all of the supersonic cases, some shock waves would occur besides the engine’s structures, esp. near the edges of the blades of the front fixed fan(s). However, its disturbance to the engine would be secondary – since it’s just a boundary surface of sudden change of the fast-flowing state (eg. the state of speed etc.). So, in order to simplify, it will be ignored the influence of the shock waves in this article.

The most urgent question is about the effects of spinning compress: Could it has a too low or too high pressure, density, flowing speed and temperature?

To answer this, the following part would simplify the spinning course and establish a set of equations for solving.

Because of the engine is designed for supersonic working, the velocity of the gas is rapid, and in comparison of this, the speed of heat transferring appears slowly. Based on this fact, the first hypothesis can be given: The fluid in spinning could be thought as adiabatic – The temperature’s change would be caused by the pressure’s work only:

\[ N d \left( \frac{i}{2} kT \right) = -p dV \]  \hspace{1cm} (1)

Moreover, the work pdV would cause the gass(es)’ kinetic energy increasing. When it is the only way:

\[ N d \left( \frac{1}{2} m v^2 \right) = p dV \]  \hspace{1cm} (1’)

Combine with (1) and (1’) can get:

\[ d \left( \frac{i}{2} kT \right) = -d \left( \frac{1}{2} m v^2 \right) \]  \hspace{1cm} (2)

Overall consider of the fluid’s mechanics equation, the constancy of the number of particles and the gas’ state function, the equations set (ref. 1) for spinning would be gained as:

\[
\begin{align*}
\text{momentum:} & \quad n m \frac{v^2}{r} = \frac{d p}{d r} \\
\text{number:} & \quad d (n V) = 0 \\
\text{state:} & \quad \rho = n k T \\
\text{adiabatic:} & \quad N d \left( \frac{i k T}{2} \right) = -p dV \\
\text{energy:} & \quad d \left( \frac{i k T}{2} + \frac{1}{2} m v^2 \right) = 0
\end{align*}
\]

Next is the main steps of a way to solve the set of equations, and its solution result:

Step 1: From (4) get: \[ \frac{dV}{V} = -\frac{dn}{n} \]  \hspace{1cm} (6)

Step 2: Take (6) and (5) into (1), and note that \[ n = \frac{N}{V} \]. Sign:

\[ C_1 = \frac{n_0}{T_0^2} \]  \hspace{1cm} (7)

The footnote 0 represent the original state (or the start state). Then could solved out:

\[ n = \left( \frac{n_0}{T_0^2} \right)^{\frac{i}{T_0^2}} = C_1 T^2 \]  \hspace{1cm} (8)

Step 3: From (2) could get: \[ \frac{i}{2} kT + \frac{1}{2} m v^2 = C \] (C is a constant)  \hspace{1cm} (9)

Step 4: From (9): \[ m v^2 = 2C - i kT \]  \hspace{1cm} (10)

Then take (10), (8) and (5) into (3), it could be solved out at the end:

\[ T = T_0 + \frac{m v^2 \text{-} i}{i k} \left[ 1 - \left( \frac{n_0}{n} \right)^{2+2i} \right] \]  \hspace{1cm} (11)

The total solution result is:

\[
\begin{align*}
T &= T_0 + \frac{m v^2}{i k T_0} \left[ 1 - \left( \frac{n_0}{n} \right)^{2+2i} \right] \\
n &= n_0 \left( \frac{T}{T_0} \right)^{\frac{i}{2}} \\
p &= p_0 \left( \frac{T}{T_0} \right)^{1+2i} \\
v &= \nu_0 \left( \frac{T}{T_0} \right)^{\frac{1}{1+2i}}
\end{align*}
\]

\[ \text{momentum:} \quad n m \frac{v^2}{r} = \frac{d p}{d r} \]  \hspace{1cm} (3)

\[ \text{number:} \quad d (n V) = 0 \]  \hspace{1cm} (4)

\[ \text{state:} \quad \rho = n k T \]  \hspace{1cm} (5)

\[ \text{adiabatic:} \quad N d \left( \frac{i k T}{2} \right) = -p dV \]  \hspace{1cm} (1)

\[ \text{energy:} \quad d \left( \frac{i k T}{2} + \frac{1}{2} m v^2 \right) = 0 \]  \hspace{1cm} (2)
Especially, from the above result could still get the limit values of the spinning compression (when \( \frac{r}{r_0} \) is little enough):

\[
\begin{align*}
\left( \frac{T}{T_0} \right)_{\text{max}} &= 1 + \frac{mv_0^2}{ikT_0} \quad (14) \\
\left( \frac{n}{n_0} \right)_{\text{max}} &= (1 + \frac{mv_0^2}{ikT_0})^{\frac{i}{2}} \quad (15) \\
\left( \frac{p}{p_0} \right)_{\text{max}} &= (1 + \frac{mv_0^2}{ikT_0})^{\frac{i+1}{2}} \quad (16) \\
\left( \frac{v}{v_0} \right)_{\min} &= 0 \quad (17)
\end{align*}
\]

The following table is some calculation results under the standard atmosphere condition for an engine with the structure character of \( \frac{r_0}{r} = \frac{1}{2} \) in different altitude and speed (the flowing along the axis is overlooked):

<table>
<thead>
<tr>
<th>H km</th>
<th>( a_0 \text{ m/s} ) (Sound velocity)</th>
<th>( T_0 \text{ K} )</th>
<th>( \rho_0 \text{ kg/m}^3 )</th>
<th>( p_0 \text{ 10}^6 \text{Pa} )</th>
<th>( M_0 \text{ 1.} )</th>
<th>( v_0 \text{ m/s} )</th>
<th>( v \text{ m/s} )</th>
<th>( T \text{ K} )</th>
<th>( \rho \text{ kg/m}^3 )</th>
<th>( p \text{ 10}^6 \text{Pa} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>340.</td>
<td>288.15</td>
<td>1.225</td>
<td>1.013</td>
<td>1.</td>
<td>339.2</td>
<td>1.841</td>
<td>1.792</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>328.58</td>
<td>268.65</td>
<td>0.9091</td>
<td>0.7011</td>
<td>3.</td>
<td>696.3</td>
<td>9.836</td>
<td>19.66</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>316.43</td>
<td>249.15</td>
<td>0.6597</td>
<td>0.4718</td>
<td>4.</td>
<td>954.2</td>
<td>18.94</td>
<td>51.87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>299.46</td>
<td>223.15</td>
<td>0.4127</td>
<td>0.2644</td>
<td>4.5</td>
<td>1022.</td>
<td>18.55</td>
<td>54.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>295.07</td>
<td>216.65</td>
<td>0.08803</td>
<td>0.05475</td>
<td>6.</td>
<td>1596.</td>
<td>12.97</td>
<td>59.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>303.13</td>
<td>228.65</td>
<td>0.01323</td>
<td>0.00868</td>
<td>8.</td>
<td>2822.</td>
<td>7.077</td>
<td>57.30</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\( \frac{r_0}{r} = \frac{1}{2}, \frac{v}{v_0} = 0.6095 \), air molecule \( m = 29 \times 1.667 \times 10^{-27} \text{kg} \), \( k = 1.380649 \times 10^{-23} \text{J/K} \), \( i = 5 \)

improved combustor. 

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In fact, this spinning compression engine isn’t perfect, even though the streamlines in it are helicoid. Compare to the common flow through the engine directly, it has just lengthened the time of gasses staying in the engine several times – seca times, \( \alpha \) is the angle between the flow speed vector and the axis line. It's still a very short period for the fuel’s complete burning in the combustor with so high-speed flowing, much more of the fuel would be wasted.

To solve this problem, an efficient improved combustor could be used – it's just needs to make out one or some ‘circular groove(s)’ on the column surface of the combustor (see Drawing 2, please.) – which can be called as 'stationed
ring(s)', and inject the fuel from the bottom or innermost space of it.

By this method, except few particles escape out through diffusion, most of the fuel injected in the groove(s) would spin there round and round until takes chemical reaction with the air rush in or diffuse inside.

Since the oxidizing agent of the engine comes from the air in the atmosphere, the total propulsive agents consuming rate of the engine would be much less than the rocket engine to produce same pushing force, let the relative specific impulse raise to near 5000.S as many air engines done. For the same reason, the craft’s take-off weight to transport an unit mass of the effective load would be reduced to ~ 1/10 in the same time.

So the spinning engine could provide for a huge amount of supersonic air-space crafts an efficient kind of pushing power and save much weight for them.

**Conclusion:**

The solution result (formulas: (8), (11), (12), (13)) and the calculation examples all shows that: 1. The speed reducing rate of the air in the bottom of the combustor is decided by the \( r_0/r \) only. 2. If the velocity of the flight could be controlled well on different altitude, then the temperature and the pressure can be kept in fair range of the structure's material bearing ability. 3. The engine can work to a high M count (~10) finally.

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References: