Preliminary Investigation of the Original 1 kW Arcjet Model

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The preliminary experimental investigation of the original model of 1 KW arcjet with nitrogen and cooled gaseous products of hydrazine decomposition was accomplished.

Principal problems of arcjet development are similar enough to problems of low-thrust liquid engines, which are to be exploited successfully long time in the space. This work is the attempt to use the experience of thruster creation for model gas arcjet development and studies with account of future application possibilities of liquid propellants based on hydrazine, UDMH, etc.

The original model of 1 KW arcjet with an electrical discharge chamber was the object of this investigation. The electric discharge chamber length and diameter and throat diameter were variables. The model arcjet was tested with variable feed pressure of nitrogen or cooled gaseous products of hydrazine decomposition.

Essential parameters of the model arcjet tests:

- Inlet gaseous propellant temperature - 15...45°C.
- Electric discharge chamber pressure - (0.5...3) \times 10^5 \text{ Pa}.
- Vacuum test chamber pressure - 10...50 \text{ Torr}.
- Electric discharge chamber length - 4.5...21 \text{ mm}.
- Electric discharge chamber diameter - 4...13 \text{ mm}.
- Throat diameter - 0.7...1.1 \text{ mm}.
- Arcjet model mass - 0.23 kg.

The power supply included high voltage oscillation and power control units. DC output voltage without charge was 630 V. Maximal test current value was approximately 11 A. corresponding minimal voltage was 50 V.

There were 707 tests: 350 start reliability tests, 196 nitrogen tests and 62 hydrazine tests with average firing time 5...10 sec. Total firing time was 3340 sec. No damaged model arcjet units were observed after tests, though refractory materials were not used in the model except boron nitride electrical insulators.

Figs. 1 through 12 show essential arcjet model test results. Maximal values of parameters: specific impulse 360 sec and efficiency 0.36 with hydrazine, 300 sec and 0.41 with nitrogen.

The theoretical estimations allow high performance possibilities for arcjet based on this model with gaseous and liquid propellants to be supposed.
Fig. 1. Electric discharge chamber pressure versus mass rate

- $L_{ch} = 4.5$ mm; $D_{ch} = 13$ mm; $D_{th} = 1$ mm;
- $L_{ch} = 19$ mm; $D_{ch} = 13$ mm; $D_{th} = 1$ mm;
- $L_{ch} = 18$ mm; $D_{ch} = 6$ mm; $D_{th} = 0.7$ mm;
- $L_{ch} = 19.5$ mm; $D_{ch} = 10$ mm; $D_{th} = 1$ mm;
- $L_{ch} = 18$ mm; $D_{ch} = 8$ mm; $D_{th} = 0.7$ mm;
- $L_{ch} = 9.5$ mm; $D_{ch} = 13$ mm; $D_{th} = 1$ mm.

Fig. 2. Consumed power versus mass rate

- $L_{ch} = 4.5$ mm; $D_{ch} = 13$ mm; $D_{th} = 1$ mm;
- $L_{ch} = 19$ mm; $U_{ch} = 13$ mm; $D_{th} = 1$ mm;
- $L_{ch} = 18$ mm; $D_{ch} = 6$ mm; $D_{th} = 0.7$ mm;
- $L_{ch} = 19.5$ mm; $D_{ch} = 10$ mm; $D_{th} = 1$ mm;
- $L_{ch} = 18$ mm; $D_{ch} = 8$ mm; $D_{th} = 0.7$ mm;
- $L_{ch} = 9.5$ mm; $D_{ch} = 13$ mm; $D_{th} = 1$ mm.

Fig. 3. Chamber pressure impulse $\beta$ versus mass rate

- $L_{ch} = 6$ mm; $D_{ch} = 6$ mm; $D_{th} = 1$ mm;
- $L_{ch} = 16$ mm; $D_{ch} = 5$ mm; $D_{th} = 1$ mm;
- $L_{ch} = 11$ mm; $D_{ch} = 6$ mm; $D_{th} = 1$ mm;
- $L_{ch} = 21$ mm; $D_{ch} = 4$ mm; $D_{th} = 1$ mm.

Fig. 4. Propulsive efficiency versus mass rate

- $L_{ch} = 6$ mm; $D_{ch} = 6$ mm; $D_{th} = 1$ mm;
- $L_{ch} = 16$ mm; $D_{ch} = 5$ mm; $D_{th} = 1$ mm;
- $L_{ch} = 11$ mm; $D_{ch} = 6$ mm; $D_{th} = 1$ mm;
- $L_{ch} = 21$ mm; $D_{ch} = 4$ mm; $D_{th} = 1$ mm.
Fig. 5. Chamber pressure impulse / versus specific power

- $L_{ch} = 4.5$ mm: $D_{ch} = 13$ mm; $D_{th} = 1$ mm.
- $L_{ch} = 19$ mm: $D_{ch} = 13$ mm; $D_{th} = 1$ mm.
- $L_{ch} = 18$ mm: $D_{ch} = 6$ mm; $D_{th} = 0.7$ mm.
- $L_{ch} = 9.5$ mm: $D_{ch} = 13$ mm; $D_{th} = 1$ mm.
- $L_{ch} = 19.5$ mm: $D_{ch} = 10$ mm; $D_{th} = 1$ mm.
- $L_{ch} = 18$ mm: $D_{ch} = 8$ mm; $D_{th} = 0.7$ mm.

Fig. 6. Propulsive efficiency versus specific power

- $L_{ch} = 4.5$ mm: $D_{ch} = 13$ mm; $D_{th} = 1$ mm.
- $L_{ch} = 19$ mm: $D_{ch} = 13$ mm; $D_{th} = 1$ mm.
- $L_{ch} = 18$ mm: $D_{ch} = 6$ mm; $D_{th} = 0.7$ mm.
- $L_{ch} = 9.5$ mm: $D_{ch} = 13$ mm; $D_{th} = 1$ mm.
- $L_{ch} = 19.5$ mm: $D_{ch} = 10$ mm; $D_{th} = 1$ mm.
- $L_{ch} = 18$ mm: $D_{ch} = 8$ mm; $D_{th} = 0.7$ mm.

Fig. 7. Electrical discharge chamber pressure versus mass rate

- $L_{ch} = 6$ mm: $D_{ch} = 6$ mm; $D_{th} = 1$ mm.
- $L_{ch} = 19.5$ mm: $D_{ch} = 10$ mm; $D_{th} = 1$ mm.
- $L_{ch} = 21$ mm: $D_{ch} = 4$ mm; $D_{th} = 0.7$ mm.

(Additional resistance $R = 10.7 \Omega$)

Fig. 8. Consumed power versus mass rate

- $L_{ch} = 6$ mm: $D_{ch} = 6$ mm; $D_{th} = 1$ mm.
- $L_{ch} = 19.5$ mm: $D_{ch} = 10$ mm; $D_{th} = 1$ mm.
- $L_{ch} = 21$ mm: $D_{ch} = 4$ mm; $D_{th} = 0.7$ mm.
Fig. 9. Chamber pressure impulse $\beta$ versus mass rate

- $L_{ch} = 6$ mm: $D_{ch} = 6$ mm: $D_{th} = 1$ mm;
- $L_{ch} = 19.5$ mm: $D_{ch} = 10$ mm: $D_{th} = 1$ mm;
- $L_{ch} = 21$ mm: $D_{ch} = 4$ mm: $D_{th} = 0.7$ mm

(\(\bigcirc\) - with additional resistance $R = 10.7 \, \Omega$);
- $L_{ch} = 11$ mm: $D_{ch} = 6$ mm: $D_{th} = 1$ mm;
- $L_{ch} = 21$ mm: $D_{ch} = 4$ mm: $D_{th} = 1$ mm.

Fig. 10. Impulsive efficiency versus mass rate

- $L_{ch} = 0$ mm: $D_{ch} = 0$ mm: $D_{th} = 1$ mm;
- $L_{ch} = 19.5$ mm: $D_{ch} = 10$ mm: $D_{th} = 1$ mm;
- $L_{ch} = 21$ mm: $D_{ch} = 4$ mm: $D_{th} = 0.7$ mm

(\(\bigcirc\) - with additional resistance $R = 10.7 \, \Omega$);
- $L_{ch} = 11$ mm: $D_{ch} = 6$ mm: $D_{th} = 1$ mm;
- $L_{ch} = 21$ mm: $D_{ch} = 4$ mm: $D_{th} = 1$ mm.

Fig. 11. Chamber pressure impulse $\beta$ versus specific power

- $L_{ch} = 6$ mm: $D_{ch} = 6$ mm: $D_{th} = 1$ mm;
- $L_{ch} = 19.5$ mm: $D_{ch} = 10$ mm: $D_{th} = 1$ mm;
- $L_{ch} = 21$ mm: $D_{ch} = 4$ mm: $D_{th} = 0.7$ mm

(\(\bigcirc\) - with additional resistance $R = 10.7 \, \Omega$);
- $L_{ch} = 11$ mm: $D_{ch} = 6$ mm: $D_{th} = 1$ mm;
- $L_{ch} = 21$ mm: $D_{ch} = 4$ mm: $D_{th} = 1$ mm.

Fig. 12. Impulsive efficiency versus specific power

- $L_{ch} = 0$ mm: $D_{ch} = 0$ mm: $D_{th} = 1$ mm;
- $L_{ch} = 19.5$ mm: $D_{ch} = 10$ mm: $D_{th} = 1$ mm;
- $L_{ch} = 21$ mm: $D_{ch} = 4$ mm: $D_{th} = 0.7$ mm

(\(\bigcirc\) - with additional resistance $R = 10.7 \, \Omega$);
- $L_{ch} = 11$ mm: $D_{ch} = 6$ mm: $D_{th} = 1$ mm;
- $L_{ch} = 21$ mm: $D_{ch} = 4$ mm: $D_{th} = 1$ mm.