# ON THE MECHANISM OF AEROACOUSTIC INITIATION OF PULSED QUASI-DETONATION COMBUSTION IN AN AIR-BREATHING EJECTOR PULSEJET*

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**Abstract:** The present paper discusses the design of a pulse-jet engine in which a new mechanism of deflagration-to-detonation transition and establishment of a mode close to the detonation combustion or quasi-detonation mode is realized. It is found that the possibility of such a transition is provided by a special design of the gas duct which has a double bend leading to the formation of a specific vortex structure of the internal flow allowing the acoustic tuning of the gas duct to reach such combustion modes.

**Keywords:** valveless ejector pulse-jet engine; double gas-jet bend; acoustic tuning; quasi-detonation; spherical detonation

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## Figure Captions

**Figure 1** Calculated flow structure inside the gas duct of an ejector pulse-jet engine: (*a*) longitudinal section; and (*b*) cross section of the combustion chamber (section $A$–$A$)

**Figure 2** Schematic diagram of the internal flow in the combustion chamber and resonator tube explaining the process of vortex development, appearance of precession, and destruction of vortices

**Figure 3** Snapshots of the temperature fields in the engine gas duct during one pulsation cycle at a frequency of 100 Hz and approaching flow velocity of 500 m/s: (*a*) beginning of a new pulsation cycle, the nucleation of the separation zone under the canopy; (*b*) start of combustion in the separation zone under the canopy; (*c*) evolution of combustion in the separation zone under the canopy; (*d*) start of gas throwing by longitudinal vortices into the separation zone under the canopy, deformation of the separation zone is visible; (*e*) evolution of the throwing process in the separation zone; and (*f*) end of the pulsation cycle

**Figure 4** Typical spectrum of pressure pulsations at the nozzle section of acoustically tuned gas duct ($L = 1410$ mm) at different frequencies of longitudinal oscillations: *1* — 100 Hz; *2* — 110; and *3* — 120 Hz

**Figure 5** Layout of the "flat" engine and a prototype installation for aeroacoustic tests, *1*, *2*, and *3* — separation zones. Dimensions are in millimeters

**Figure 6** Calculated flow structure inside the gas duct of the "flat" engine

**Figure 7** Spectra of acoustic oscillations at an excitation frequency of 120 Hz and different length of the resonator tube: *1* — 1300 mm; *2* — 1360; *3* — 1380; *4* — 1400; and *5* — 1420 mm. Blowing velocity is 60 m/s, "flat" gas duct

**Figure 8** Schematic layout of the gas duct with a cylindrical combustion chamber. Dimensions are in millimeters

**Figure 9** Internal flow in the gas duct at a blowing velocity of 60 m/s

**Figure 10** Variation of the circumferential vortex velocity $W_r$ depending on the blowing velocity $W$ for different engine gas duct designs: *1* — design of Fig. 1; and *2* — design of Fig. 6

**Figure 11** Spectrograms of acoustic pressure pulsations (frequency 120 Hz): *1* — 1350 mm without blowing; *2* — 1350 mm, $W = 60$; *3* — 1370 mm; *4* — 1385; *5* — 1400; and *6* — 1430 mm

**Figure 12** Schematic of the experimental installation. Dimensions are in millimeters

**Figure 13** Spectrograms taken at the 1380-millimeter gas duct, 60 m/s: (*a*) 90 Hz; (*b*) 100; and (*c*) 110 Hz; *1* — combustion chamber; and *2* — nozzle cross section

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**Figure 14** Spectrograms taken at the 1410-millimeter gas duct, 60 m/s: (*a*) 90 Hz; (*b*) 100; and (*c*) 110 Hz; *1* — combustion chamber; and *2* — nozzle cross section

**Figure 15** Schematic illustration of the flow in the combustion chamber

**Figure 16** Idealized pulsed combustion cycle represented as pressure changes in the combustion chamber

# References

1. Frolov, S. M., ed. 2006. *Impul'snye detonatsionnye dvigateli* [Pulse detonation engines]. Moscow: TORUS PRESS. 592 p.
2. Frolov, S. M., V. S. Aksenov, V. S. Ivanov, I. O. Shamshin, and S. A. Nabatnikov. 2019. Broskovye ispytaniya bespilotnogo letatel'nogo apparata s pryamotochnym vozdushno-reaktivnym impul'sno-detonatsionnym dvigatelem [Catapult launching tests of an unmanned aerial vehicle with a ramjet pulsed-detonation engine]. *Goren. Vzryv (Mosk.) — Combustion and Explosion* 12(1):63–72.
3. Migalin, K. V., K. A. Sidenko, and K. K. Migalin. 2020. *Ezektornye pul'siruyushchie vozdushno-reaktivnye dvigateli* [Ejector pulsed air jet engines]. Togliatti: Spectrum Publishing House. 444 p.
4. Migalin, K. V., and K. A. Sidenko. 2021. O razrabotke vozdushno-reaktivnogo dvigatelya, realizuyushchego tsikl goreniya, priblizhennyy k detonatsionnomu [On the development of an air-jet engine implementing a combustion cycle close to the detonation cycle]. *Goren. Vzryv (Mosk.) — Combustion and Explosion* 14(1):29–37.
5. Migalin, K. V., K. A. Sidenko, and K. K. Migalin. 2021. *Ezhektornye dvukhkonturnye pul'siruyushchie vozdushno-reaktivnye dvigateli dlya okolo i sverkhzvukovykh skorostey poleta* [Ejector double-circuit pulsejets for transonic and supersonic flight speeds]. Togliatti: Spectrum Publishing House. 121 p.
6. Knysh, Yu. A., and A. F. Uryvskiy. 1984. Model of swirled jet vortical core precession. *Soviet Aeronautics* 27(3):48–50.
7. Gupta, A. K., D. G. Lilley, and N. Syred. 1984. *Swirl flows*. Turnbridge Wells, England: Abacus Press. 488 p.

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