# ROTOR-VANE COMPRESSOR WITH CONTACTLESS SEALS OPTIMIZATION

A.G. IVANUSHKIN[1], I.V. KOLOMIN[2]
Aircraft Engine department,
Samara State Aerospace University, the city of Samara, Russia
[1]aleksei-383@mail.ru, [2]kolomin@list.ru

**Abstract:** Rotor-vane compressor (RVC) optimization ways are presented to improve RVC characteristics. The prospect of RVC use in the structure of gas cryogenic refrigerators (GCR) is shown.

**Keywords:** Rotor-vane compressor, groove seal, leakages.

### Introduction

The modern refrigeration machines running, for example, on the basis of Stirling cycle within the compressor unit design are based on reciprocating motion of the pistons, implemented through a crank-and-rod mechanism (CRM) or by a linear electric drive.

The achieving of operation chamber tightness require contact seals installation at the use of a crank-and-rod mechanism, and the "absence of contact" for pistons which are the part of a linear electric drive, is achieved by the increasing design complexity, which reduces the resource. The rotary vane compressor being developed has guaranteed minimum clearances in groove seals around the blade perimeters.

The RVC working area where the processes of compression and expansion occur represents an annular chamber of variable volume, for example, of rectangular cross section with a single vibrating blade inside or in pairs of blades that perform the piston function.

### Methods

The closed volume of four working chambers 3 shown by Fig. 1 is formed between the fixed walls of the housing 1 and two movable blades 2, performing reciprocating rotary motion. The workflow of four-chamber RVC is organized so that while one pair of working chambers performs a compression and exhaust stroke, the other pair of working chambers performs an intake stroke. The inlet and exhaust of an operating body is produced through the openings 4 located at housing points where the blades meet.

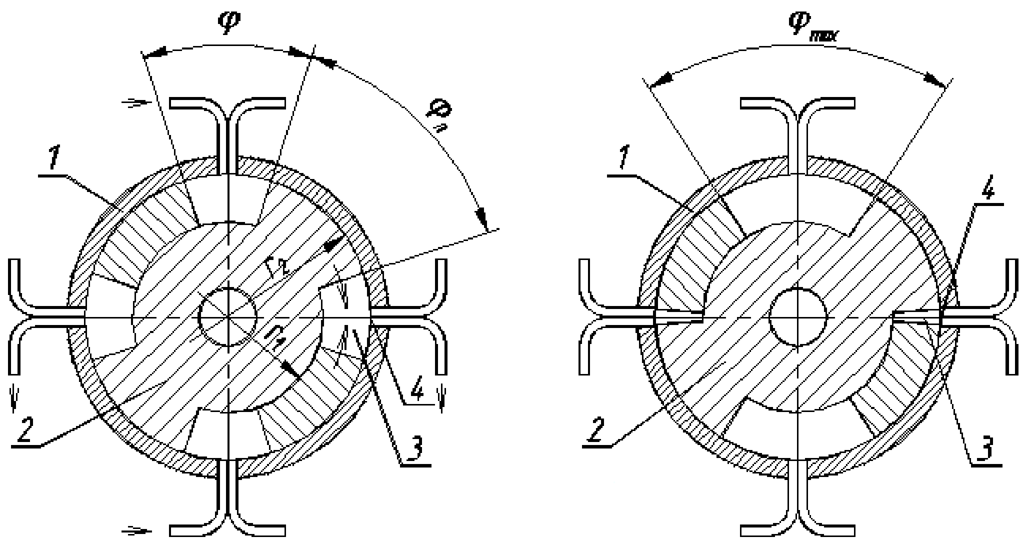


Fig.1. Four chamber rotor-vane compressor operation scheme

Due to the fixation of the shaft (shafts) the RVC in the housing with bearings the application of force on the housing wall is excluded (as opposed to CRM, where there are forces from stocks at the transposition of a piston). This allows the use of contactless seals around the perimeter of the blades and thereby substantially reduces the friction loss. The use of appropriate materials in the RLC housing and blades design ensures a constant gap and reliable operation of non-contact seals.

The performed calculations [1] and tests [2] of rotary vane compressor showed the need for its design improvements. Such factors as non-optimal geometry of the operation cavities for RLC prototypes and the crevice gap in the blade connector plane substantially reduce the compressor performance.

In order to eliminate these drawbacks the new RLC design is designed while maintaining the same working volume $V_p = 41{,}9\times10^{-6}$ m$^3$, i.e. the required consumption $Q_в = 419{,}8\times10^{-6}$ m$^3$/s and the outer radius limit $r_2 = 70$ mm.

This variant of a rotary vane compressor (RVC-2) was carried out on a rocking scheme with one pair of oscillating and one pair of fixed blades. The use of one oscillating rotor by RVC-2 instead of two oscillating rotors allows to avoid additional leaks in the compressor crankcase, which take place in a rotor-blade machine [2].

The methodology the block diagram of which is shown in Fig. 2, is used to optimize the annular channel shape through the gap according to the leakage minimization criterion. The calculation formula for the gas flow through a smooth slot is the following [1]

$$Q_{ЩУ} = \frac{П_п \cdot (p_2 - p_1) \cdot \delta^3}{12 \cdot \mu \cdot l_{эк}}. \quad (1)$$

The geometric parameters of the operational cavities are optimized according to the developed methods [1] and are summarized in a comparative table 1.

The assembly drawing fragment of modernized RVC-2 is shown in Fig. 3.

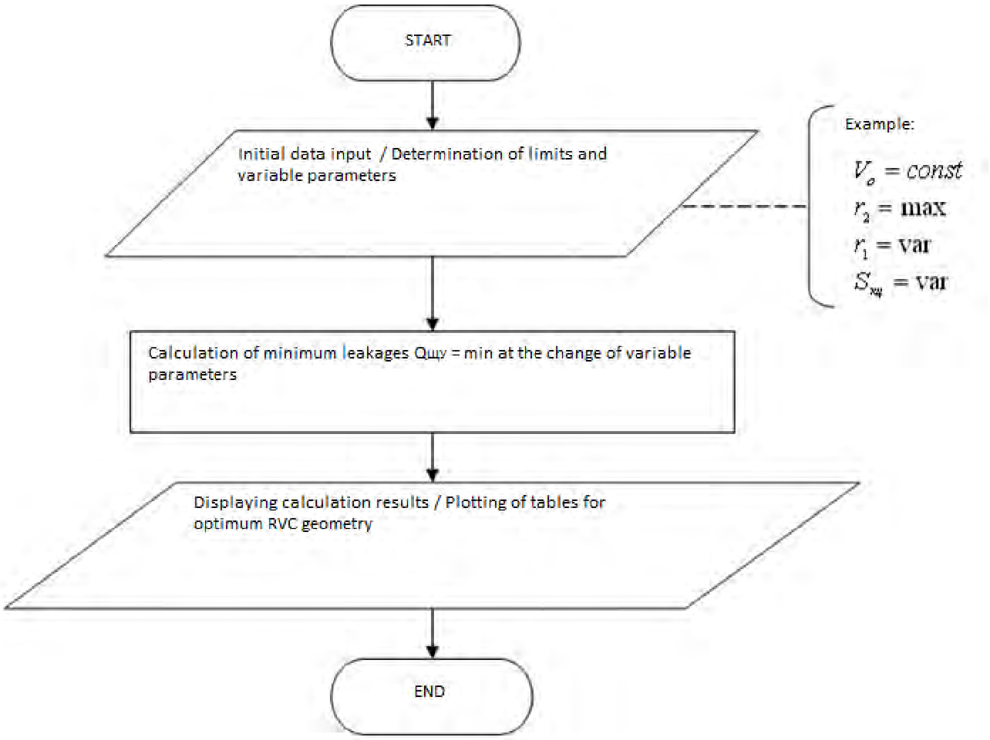


Fig. 2. Block diagram of rotor-blade compressor geometry algorithm optimization

Table 1. Main geometric parameters of non-optimized and modernized versions of the rotor-vane compressor

| Parameter | Designation | RVC-1 | RVC-2 |
|---|---|---|---|
| Internal radius, m | $r_1$ | $23{,}0\times10^{-3}$ | $60{,}0\times10^{-3}$ |
| External radius, m | $r_2$ | $35{,}0\times10^{-3}$ | $70{,}0\times10^{-3}$ |
| Ring thickness, m | $S_{кц}$ | $24{,}0\times10^{-3}$ | $10{,}3\times10^{-3}$ |
| Relative piston perimeter, m | $П_п$ | $72{,}0\times10^{-3}$ | $40{,}6\times10^{-3}$ |
| Blade deviation angle | $\varphi_{\max}$ | $72^\circ$ | $90^\circ$ |
| The angle of movable blade arc length | $\varphi_л$ | $54^\circ$ | $60^\circ$ |
| Equivalent slot length, m | $l_{эк}$ | $27{,}3\times10^{-3}$ | $68{,}1\times10^{-3}$ |

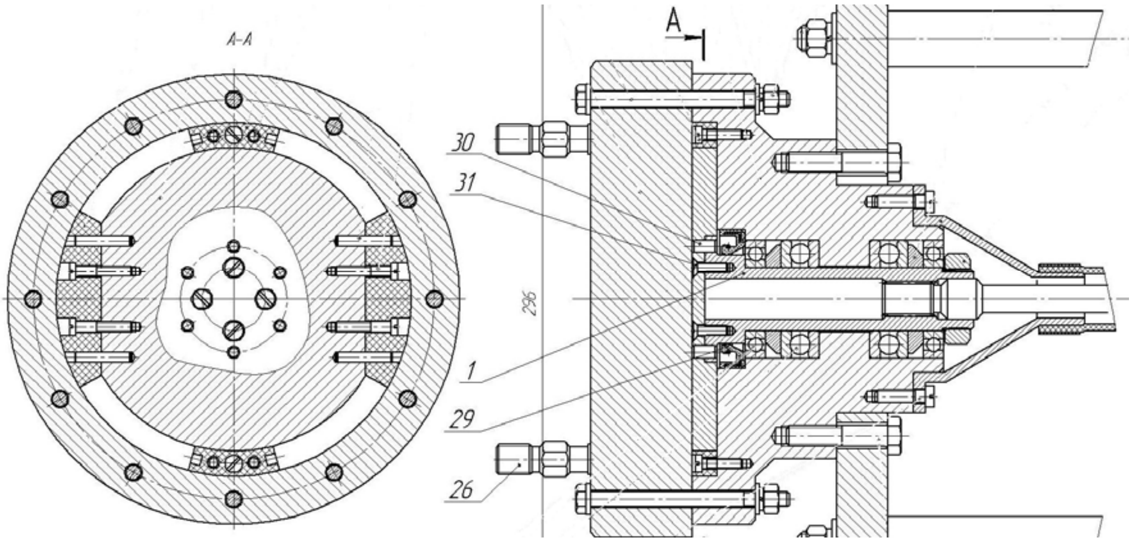


Fig. 3. Modernized rotor-blade compressor

The use of two fixed blades allows to increase the compressor leaktightness at least twice, due to the exclusion of the working fluid leakages along the blade perimeter. The elongation of the movable blade arc from $\varphi_л = 54^\circ$ to $60^\circ$, and, respectively, the increase of an equivalent slot length while reducing the relative piston perimeter also helps to reduce leakages. Due to the use of a swinging rotor instead of two ones the leakages in the compressor crankcase are significantly reduced.

The corresponding technique is developed [1], which allows to find the mass of gas transferred through the gap seals during the compression and exhaust process to determine the RVC working cavity tightness:

$$m_{пер} = \int_{\tau_1}^{\tau_2} Q_{ЩУ}(\tau)\cdot \rho_{ср} \cdot d\tau. \qquad (2)$$

As the result of revised design the tightness factor of RVC-2 calculated as described in [1], makes $\lambda_г = 0{,}95$ for the slot gap value of $\delta = 20$ mcm, and the compressor performance is increased by 29.4% compared to the non-optimized RVC. This allows to achieve the required performance of $Q_в = 419{,}8 \times 10^{-6}$ m$^3$/s by the equivalent increase of operating frequency up to $f_p = 11{,}3$ Hz or just by 13,4%, and not by 25%, as for the case of optimization under the restriction of the outer radius $r_2 = 55$ mm (fig. 4, 5, 6 [1]).

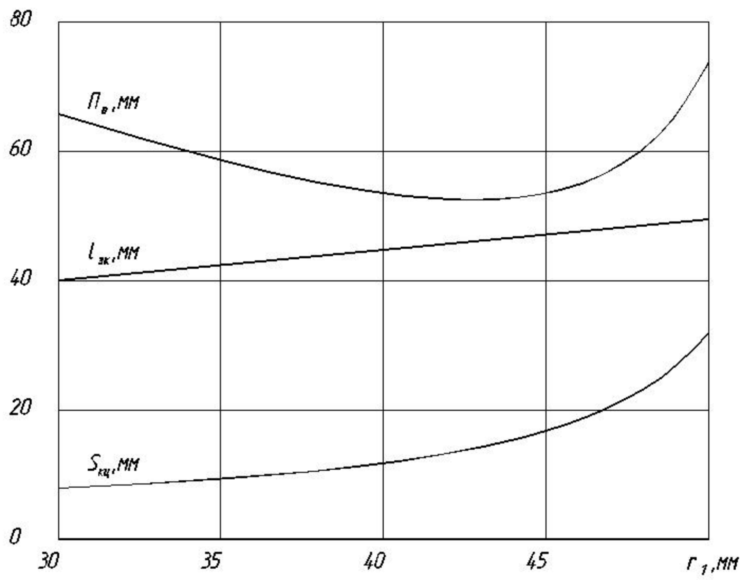


Fig. 4. Relative piston perimeter, the equivalent length and the annular channel thickness dependence on the inner radius

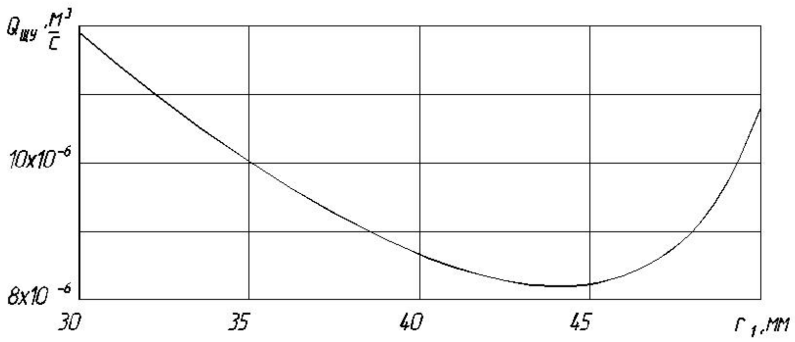


Fig. 5. The dependence of the working fluid leaks through a smooth gap on the inner radius

It should be noted that for the non-optimized version of the rotary-vane compressor the performance $Q_в = 419{,}8 \times 10^{-6}$ m$^3$/s is achieved only at the operating frequency of $f_p = 14{,}7$ Hz, that is, when its increase in one and a half time relative to the theoretical frequency of the working volume change $f = 10{,}0$ Hz (see fig. 6).

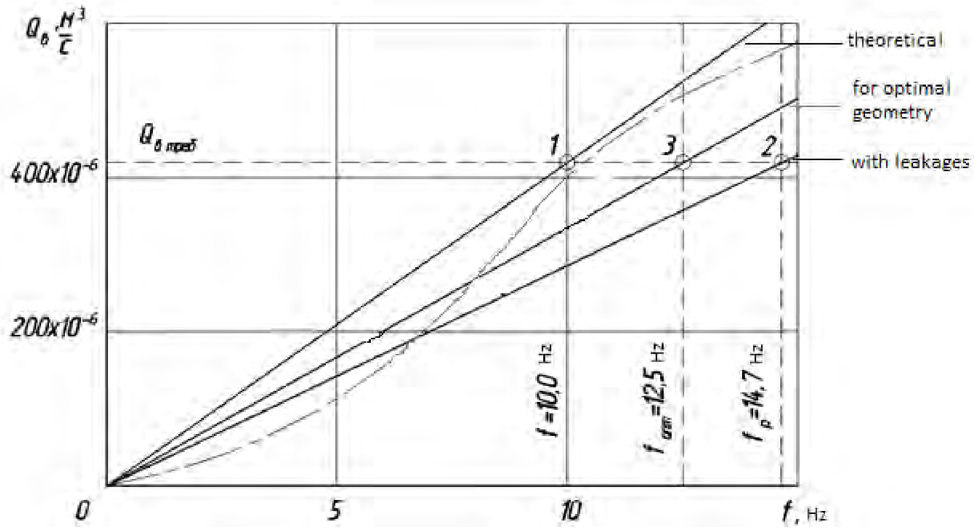


Fig.6. The dependence of performance on the compressor working volume change frequency

[3] shows that the working fluid leakages have a significant impact on the CRM operation, which includes RVC. Therefore, the implementation of geometric optimization during the design phase allows to obtain the characteristics of rotary vane compressor, increasing the efficiency of its work in the gas cryogenic machine.

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**INFO ABOUT AUTHORS**


Ivanushkin Alexey Gennadyevich, a graduate student of heating equipment and heat engines SSAU, e-mail: aleksei-383@mail.ru, main research interests: heat engine workflows.

Kolomin Ilya Viktorovich, Ph.D., Associate Professor of Thermal Engineering and heat engines SSAU department, e-mail: kolomin@list.ru, main research interests: workflow processes of thermal engines and cooling systems, on-board micropower.