

# FREQUENCY OF THE SELF VIBRATING CHAMBER WITH CONTINUOUS PASSAGE OF LIQUID

## ЧАСТОТА САМОСТОЯТЕЛЬНО ВИБРАЦИЯ ПАЛАТЫ С НЕПРЕРЫВНЫМ ТЕЧЕНИЕМ ЖИДКИХ

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**Abstract:** The study deals with frequency of the self vibrating chamber with continuous passage of liquid that is constructed as analogy to theory of acoustic elements and the paper contains the experimental results obtained from laboratory technical practice. We can also demonstrate and regulate the conformity of the hypothetical frequency with the one measured in laboratory. The paper mainly presents calculation of various converting (relative correcting correlation) coefficients for practical prediction of vibrations of the water-dynamic acoustic instantaneous oscillating system. Implementation of coefficients denotes determination of acoustic resistance and drag force in the mathematical analytical model of vibrations, because theoretical interpretation of impacts of drag forces is questionable especially for strong turbulent flow. The paper refers also to the necessity of the respect of mathematical and physical conditions for functionality of the vibration model of the water-dynamic acoustic instantaneous oscillating system.

**KEYWORDS:** PULSE JET, FREQUENCY, VIBRATING CHAMBER

### 1. Introduction

At the present technical practice, lots of disintegration alternatives for the working material surface are used. One of these alternatives is the action of the high-speed flowjet (in our case waterjet). To increase the cost-effectiveness of the wrack by waterjet we can see in the technical practice a sporadic implementation of the vibration and resonance chamber, which we refer to the Helmholtz acoustic chamber (exactly König cylindrical acoustic chamber). Generated high-frequency water flow is then modulated, in transferred to the pulsejet. The use of technologically various principles differs in the physical meaning and so in the pragmatist meaning above all economically. The optimum variant for the future we see the combination of the applications, for example device for creation of pulse oscillations with tunable appliance for intensification these oscillations (with support resonance).

### 2. Problem Definition

Real hydrodynamic acoustic system is generally the flow tube with capacious cavity, where is installed volume chamber (Fig.1). Such system is mathematically represented by the model with continuous distributed characteristic acoustic parameters: the acoustic mass  $m_a$  and the acoustic resistance  $r_a$ , the acoustic plasticity  $c_a$ , related to comprehensively the acoustic impedance  $Z_a$  [1]. Elements of the system - tubes (see Fig. 1: input tube 1, connecting tube 4, output tube and nozzle 6, 7) are described with acoustic parameters  $m_a$  and  $r_a$ , their parameter  $c_a$  is insignificant. Elements of the system - chambers (see Fig. 1: capacious chamber 2, 3, 5) are determined by acoustic parameter  $c_a$ , their acoustic parameters  $m_a$  and  $r_a$  have smaller impact for a functionality. In that case of the liquid supporting surroundings this impact is significant, because water has a poor compressibility in comparison with gas. The analytical model of the primary frequency is formulated by analogy to acoustic circuits with gas (air) and by agreement with electric-magnetic circuits [2]. For the liquid supporting surroundings we approximated only newly acoustic characteristic parameters. Firstly, the physical conditions must be respected, as to an element (component of the part of the system) functions as a tube and when as to a chamber [3]. Actually positive classification for functionality isn't just reciprocal relationship of the geometric dimension of tubes and of the chambers. Hydrodynamic acoustic system is often the system with many elements and we consider it as a complex with specific qualities. The certain acoustic element must not physically and automatically represent the theoretically equipollent acoustic parameter. This element can be influenced by standard neighbor parameters. The functionality of the composite system can reduce the functionality of the simple system with small

number elements. Pursuant of the comparison real impact Newton force (resistance hydrodynamic force  $F_{res}$ ) and acoustic force we deduced universally the partial acoustic mass  $m_a$  and after total acoustic mass  $m_{ain}$  for i-tube.

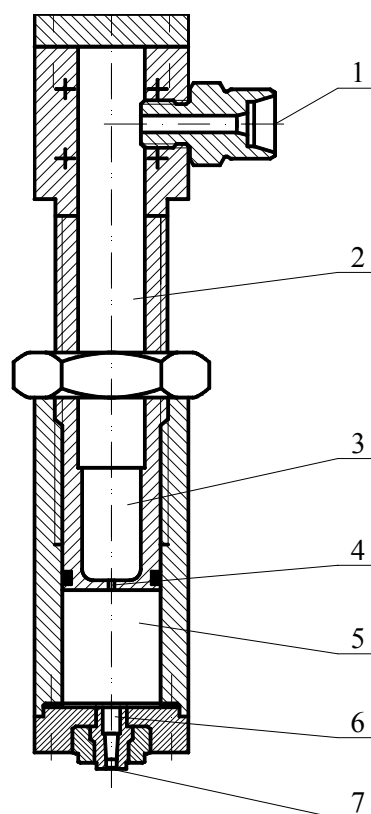


Fig. 1. Scheme of the hydrodynamic oscillating system.

$$m_{ai} = \frac{\rho l_i \left( p - \frac{1}{2} \rho v_i^2 \right)}{k_{res} \rho \pi r_i^2 v_i^2 + \left( p - \frac{1}{2} \rho v_i^2 \right) \pi r_i^2}; k_{res} = 2;$$

$$\text{where } m_a = \sum_{i=1}^n m_{ai}$$

All potentially prognosticately acoustic mass does not vibrate just in reality, but only its part as the determinate  $k$ -multiple of the

theoretical value. Because actual acoustic masses  $m_{asi}$  of all tubes are vibrating in the hydrodynamic system together in the one complex, we presume approximately, that converting coefficient exists identical or similar for all tubes and chambers in given system, so for practical total acoustic mass  $m_{as}$ , the equation is (1):

$$m_{as} = \bar{k}_{rec} m_a \quad (1)$$

Introduction of the converting coefficient (the relative correction correlation coefficient „ $k_{rec}$ “) gives the precision to resistance force  $F_{res}$  evaluation, which is not in correspondence with theoretical prediction for powerful turbulent water circulation. The measurement result in the concrete case is able to change, because we determine the influence of the change in the practice exclusively experimentally. General conditions for the size of the acoustic mass and consecutively also acoustic impedance of tubes are complicated in the case real fluid, because we determine them only by laboratory physical measuring mostly. We need deal sizes of hydrodynamic resistance force as a fundamental question for the solution of the acoustic frequency, amplitude and energy of the vibrating hydrodynamic system (our reasons are in the first place: friction between liquid and wall, viscosity, turbulence etc.). We can derive the mechanical plasticity  $c$ ; partial acoustic plasticity  $c_{aj}$  for  $j$ -chamber and total acoustic plasticity for hydrodynamic acoustic system by way of relationships (for compressibility, equation of the continuity and the Bernoulli' equation):

$$c_{aj} = \frac{\pi r_j^2 l_j}{p - \frac{1}{2} \rho v_j^2}; \text{ where } \frac{1}{c_a} = \sum_{j=1}^m \frac{1}{c_{aj}} \quad (2)$$

Where we adjust acoustic pressure  $p$  of vibrations (as a consequence of the pump pressure) as around constant (5 MPa right to 25 MPa), then velocity of liquid jet, phase velocity, velocity of oscillating particle, liquid density, compressibility and viscosity are modified as consequence of the change of the sizes of the cross-section of tubes and chambers. We can compose universal kinetic equation and deal it as a simple differential approximately linear of the second level with constant coefficients (in correspondence with acoustic circuits and electric and magnetic circuits) for primary resonance frequency  $f_0$ . We are able to find in this equation primary theoretical resonance frequency  $f_0$  and we are then able to compare it with measured resonance frequency  $f_M$ :

$$f_0 = \frac{1}{2\pi} \sqrt{\frac{1}{m_a c_a}} \wedge f_M = \frac{1}{2\pi} \sqrt{\frac{1}{\bar{k}_{rec} m_a c_a}} \quad (3)$$

The converting coefficient  $k_{rec}$  is expressed analytically in dependence on acoustic characteristic parameters ( $m_a$ ,  $c_a$ ) of the given hydrodynamic acoustic system and on some selected discreet pilot measurements of the frequency  $f_M$  of the given hydrodynamic acoustic system:

$$k_{rkk} = \frac{1}{4\pi^2 f_M^2 m_a c_a} \quad (4)$$

The converting coefficient represents (simple said) resistance attributes of the concrete hydrodynamic acoustic flowage system. In agreement with our requirements for prediction and for accurateness we can calculate converts coefficient  $k_{rec}$  (verbatim and exactly:  $\bar{k}_{rec}$  expected value for converts coefficient, so relative correcting correlation and so coefficient of theory to practice conversion) one-shot a later use it for given system as the specific material and geometric constant. By similar way (by combination of direct measurements and of indirect measurements – calculations) we can create following models of converting coefficients for forced oscillations and for subdued oscillations. In laboratory conditions

we can escalate the category accuracy of calculation of the converting coefficient „ $k_{rec}$ “, but in dependence on accuracy of the substitute measuring values. For timely technical and practical requirements we consider as sufficient accuracy approximately 10% (in Tab.1:  $\sigma_k$  is relative uncertainty of the result of the converting coefficient;  $\sigma_{\Delta k}$  is relative gap between values of the frequency  $f_0$ ;  $f_m$ ).

Table 1. Illustration of the concrete result of the converts coefficient

| $\bar{k}_{rec}$ |                           |                |            |            |                |
|-----------------|---------------------------|----------------|------------|------------|----------------|
| n.              | $k_{rec}$                 | $\sigma_k$ [%] | $f_m$ [hz] | $f_0$ [hz] | $\sigma_M$ [%] |
| 1.              | $8,00 \cdot 10^{-4}$      | 10,00          | 5200       | 4797       | 6,44           |
| 2.              | $1,12 \cdot 10^{-3}$      |                | 6200       | 6777       |                |
| 3.              | $9,39 \cdot 10^{-4}$      |                | 8300       | 8292       |                |
| 4.              | $1,06 \cdot 10^{-3}$      |                | 9000       | 9565       |                |
| 5.              | $7,84 \cdot 10^{-4}$      |                | 11700      | 10683      |                |
|                 | $\bar{k}_{rec} 0,0009406$ |                |            |            |                |

### 3. Conclusion

Some characteristic parameters of the hydrodynamic acoustic system (for example an influence of the sharpes of the crossing of the elements we do not quantify) are difficult for laboratory measurement, because the universal model of the hydrodynamic acoustic system requires the creation of the concrete model given hydrodynamic acoustic system by way of use converting coefficient (relative correction correlation coefficient). We recorded satisfactory accuracy of results of the mathematical model frequency compared to the results of laboratory measurements (approximately 6%) for data file of the direct measurements of the frequency.  $\sigma_k$  relative uncertainty of the result of the converting coefficient is 10% and 6% is  $\sigma_{\Delta k}$  relative gap between values of the frequency  $f_0$ ;  $f_m$ , we consider as suitable for technical and practical requirements. With given concrete converting coefficient we can model and interpolation (pertinently proportionally extrapolation) the continuous value primary frequency of the hydrodynamic acoustic system according to pump pressure and to geometrical dimensions of the system. Certain method for valorization of the efficiency of the modulated and pulse of the waterjet is exhaustive experimental analysis of surfaces generated by abrasive waterjet [4].

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