

Застосування рідинних автобалансирів для компенсації експлуатаційних змін дисбалансу роторних систем без їх зупинки становить інтерес через відносну конструктивну простоту цих пристроїв, які є пасивними регуляторами прямої дії, що не потребують підведення енергії і системи керування для переміщення коригувальних мас. Відсутність досліджень впливу в'язкості рідини на ефективність автобалансування і обґрунтованості підбору рідини при конструюванні рідинних АБП поставило вимогу проаналізувати роботу рідинного АБП в реальній системі з врахуванням впливу властивостей рідини на ефективність процесу балансування вертикального ротора. Показано, що ефективність балансування зростає при наближенні кутової швидкості до критичної і при збільшенні зовнішнього опору; для рідинних АБП масові сили робочої рідини мають менший вплив на ефективність балансування ніж сили в'язкості.

Ключові слова: ротор, критична швидкість, дисбаланс, автоматичне балансування (самобалансування), ефективність балансування, автобалансируючий пристрій (АБП), в'язкість робочої рідини.

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THE FLUID BALANCER STUDY: INFLUENCE OF THE VISCOSITY OF A LIQUID WORKING BODIES

The use of liquid auto-balancers to compensate for the operational changes in the imbalance of rotary systems without stopping them is of interest because of the relative structural simplicity of these devices, which are passive direct-acting regulators that do not require power supply and control systems to move correction masses. The experience of the study of passive auto-balancing devices (ABD) indicates that the existing theory (statements) of passive automatic balancing of the fluid is idealized and inaccurately describes the processes that occur with the working bodies during their operation. In particular, the lack of studies on the effect of liquid viscosity on the efficiency of self-balancing and the reasonableness of the selection of liquid during the construction of fluid ABD demanded to analyse the operation of liquid ABD in the real system, taking into account the influence of liquid properties on the efficiency of the vertical rotor balancing process. It is shown that the: automatic fluid balancing is effective for elastically de-formable rotors, on elastic supports ones, where there is a phase difference between the direction of force from the imbalance and the rotor deflection or the displacement of the rotor; automatic balancing with the help of liquid working bodies of different densities for the vertical rotor exists at the pre-resonance, after resonance (operating) frequencies and at resonance; the efficiency of balancing increases with the approach of the angular velocity to the critical one and with the increase of the phase angle, that is, with the increase of the external resistance; liquid density does not significantly influence the optimal filling of the ABD chamber on the process of self-balancing over the entire frequency range of the rotor; the viscosity significantly affects the vibration of the rotor, even with optimum filling. Consequently, for the liquid ABD, mass forces have less effect on the balancing efficiency than the viscosity; when the chamber is filled with more liquid than the optimal volume, there is a deterioration in the efficiency of the balancing, which can be explained by the presence of waves on the free surface of the liquid, which causes a dynamic instability in the work of the machine.

Keywords: Rotor, critical speed, imbalance, automatic balancing (self-balancing), balancing efficiency, auto balancing device (ABD), working fluid viscosity.

1916

(Leblanc)

[3].

(E.L. Thearle) [4].

E.L. Thearle

[5], [6], H.S. Hoon, L.J. Young, S. Suzuki [7], [8, 9], Chung-Hyo Jung, Chang-Sub Kim, Yun-Ho Choi [10], M.A. Langthjema, T. Nakamurab [11], Cunico M.W.M. [12], H.-W. Chen, W.-X. Ji, Q.-J. Zhang, Y. Cao and S.-Y. Fan [13]

Internet

LG Electronics Inc. [14, 15], Whirlpool Corporation [16], SKF AutoBalancer Systems [17], Samsung Electronics Co. Ltd [18].

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R h

$$\bar{D}_c = \bar{D} \cdot \frac{m}{m+M} \quad (1)$$

$$\bar{D}_0 = \bar{D} \cdot \frac{M}{m+M} \quad (2)$$

$$\bar{OC} = \bar{e} = \frac{\bar{D}}{m+M} \quad (3)$$

$$\bar{OC}_0 = \bar{e}_0 = \frac{\bar{D}_0}{m+M} \quad (4)$$

$$\bar{OC}_c = \bar{e}_c = \frac{\bar{D}_c}{M+m} \quad (5)$$

[1].

$\omega < \omega$

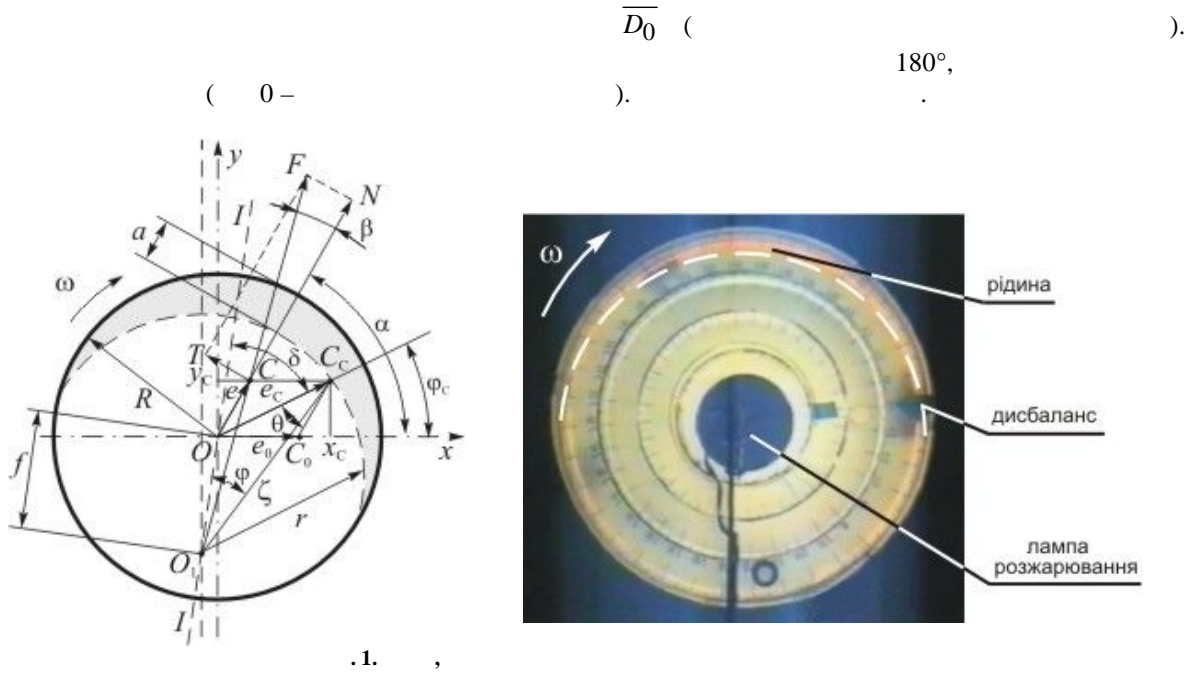
(I-I)

(OC) (1).

$$\bar{D}_c = (M+m) \cdot \bar{e}_c \quad \bar{D}_0 = M \cdot \bar{e}_0 \quad (6)$$

$$\bar{D} = m \cdot \bar{e} \quad (7)$$

\bar{D}_0 (



1.

$$e_c = \sqrt{x_c^2 + y_c^2} = e\sqrt{1 + 2k \cos \alpha + k^2}.$$

$$k = \frac{D_0}{D} -$$

$$\text{tg } \alpha = 0, \quad f[\text{tg } \alpha \cos(\delta + \varphi_c) - \sin(\delta + \varphi_c)] = 0.$$

(= 0):

$$f = 0; \quad \text{tg } \alpha_0 \cos(\delta + \varphi_{0c}) - \sin(\delta + \varphi_{0c}) = 0. \quad (1)$$

(1))

$$\text{tg } \alpha_0 = \text{tg}(\delta + \varphi_{0c}).$$

$$e, e/e_0, e_c, \quad \sin \alpha_0 = \frac{1}{k} \sin \delta \sqrt{1 + 2k \cos \alpha_0 + k^2}. \quad (2)$$

(2)

(= 0, k > 0)

(= 0),

(6) 0, k > 0

(= 0):

$$\alpha_0 = \pi - \arccos\left(\sin^2 \delta + \sqrt{(\sin^2 \delta - 1) \cdot (\sin^2 \delta - k^2)}\right) \quad (3)$$

(3),

$$\delta \in \left(0, \frac{\pi}{2}\right) \quad \alpha_0 \in \left(\frac{\pi}{2}, \pi\right);$$

0:

$$\lambda_0 = \frac{k}{\sqrt{1 + 2k \cos \alpha_0 + k^2}}; \quad (4)$$

$$1 + 2k \cos \alpha_0 + k^2 = 0$$

$$k = 1 \quad \cos \alpha_0 = -1,$$

(k > 1).

[19].

[20].

[20]

$$\Delta P = \frac{4F_T}{\pi d^2},$$

$d -$

$$F_T = \frac{\pi}{4} \Delta P \cdot d^2.$$

[19]

$$\Delta P = \rho \cdot g \cdot \lambda \frac{l}{d} \frac{v^2}{2g} = \rho \lambda \frac{l}{d} \frac{v^2}{2},$$

$l -$
 $v -$

($Re < Re$)

$$\lambda = \frac{64}{Re},$$

[20].

$$Re = \frac{vd}{\nu} = \frac{v\rho d}{\mu}$$

($-$, $\mu -$,) , $\lambda = \frac{64 \cdot \mu}{v\rho \cdot d}$. ,

$$\begin{aligned} F_T &= \frac{\pi}{4} d^2 \cdot \rho \lambda \frac{l}{d} \frac{v^2}{2} = \frac{\pi d^2 \rho \cdot 64 \mu \cdot l \cdot v^2}{8 d^2 \cdot v \rho} = 8 \pi \mu \cdot l \cdot v = 8 \pi \mu \cdot \frac{\pi R \xi}{180} \cdot \omega \cdot |\overline{O_1 C}| = \\ &= \frac{8 \pi^2 \mu \cdot R \xi \cdot \omega}{180} \sqrt{(e \cos \alpha + f \cos(\delta + \varphi_c))^2 + (e \sin \alpha + f \sin(\delta + \varphi_c))^2}, \end{aligned} \tag{5}$$

(7)

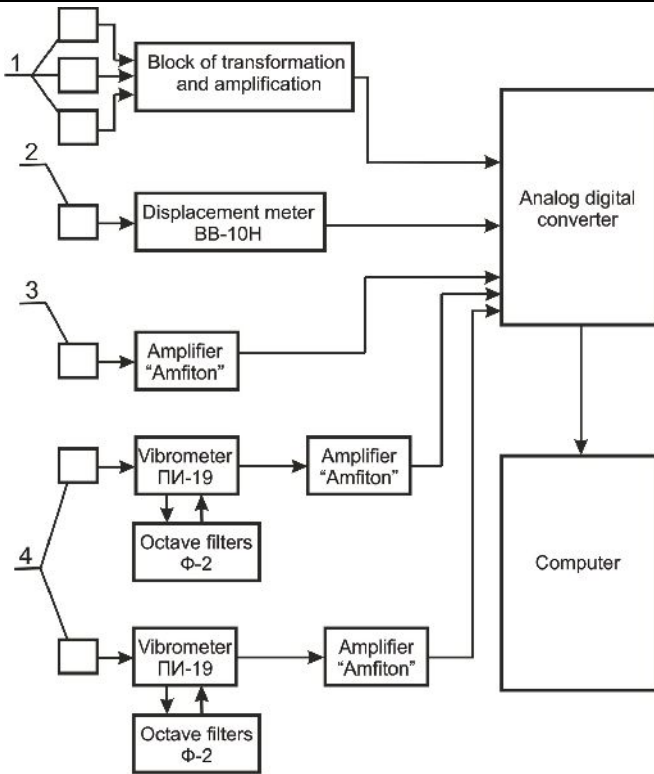
(F_T)

(T)

$$: F_T = T \quad , \quad T = F \cdot \sin \beta \quad , \quad \sin \beta = \frac{F_T}{F}$$

$$\sin \beta = \frac{8 \pi^2 \mu \cdot R \cdot \xi \cdot \omega |\overline{O_1 C}|}{180 \cdot m \cdot \omega^2 |\overline{O_1 C}|} = \frac{8 \pi^2 \mu \cdot R \cdot \xi}{180 \cdot m \cdot \omega} . \tag{6}$$

$$tg \beta = \frac{\sin \beta}{\pm \sqrt{1 - \sin^2 \beta}} .$$



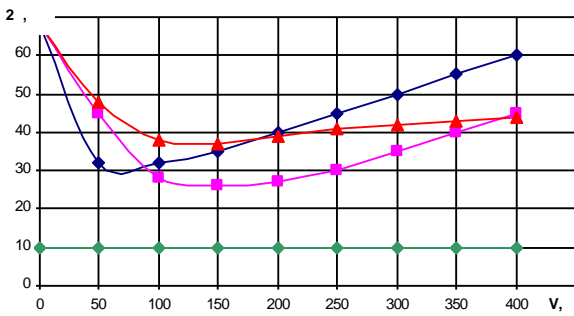
1 - ; 2 - ; 3 - ; 4 - ;

150

150-200

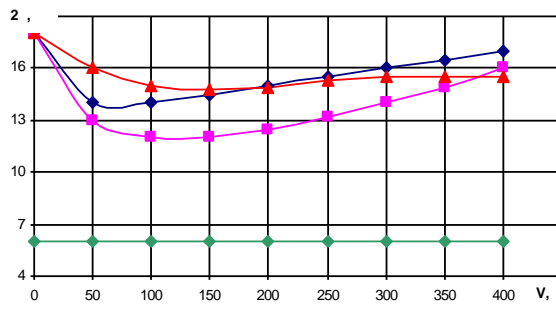
100 (D=2000)

[4]



Legend for Graph 3: Blue diamond, Red triangle, Magenta square, Green circle

3.



Legend for Graph 4: Blue diamond, Red triangle, Magenta square, Green circle

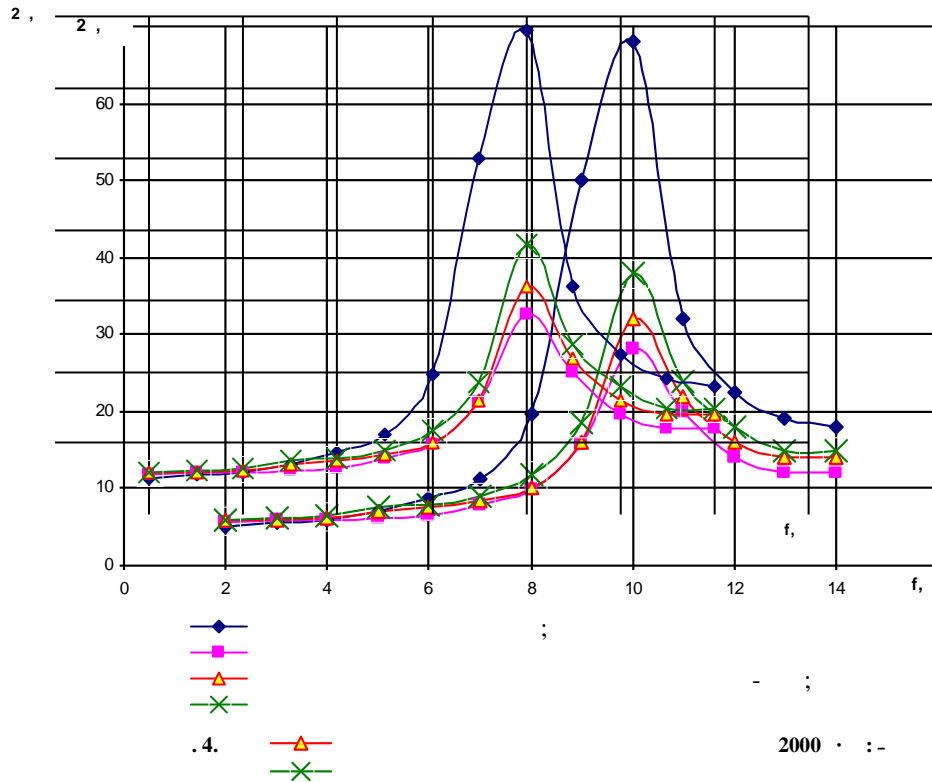
4

100

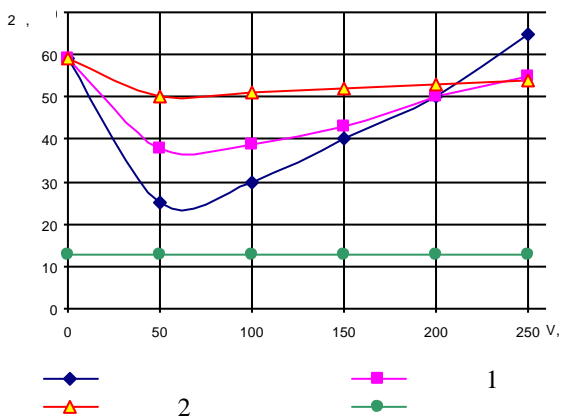
2000

40%

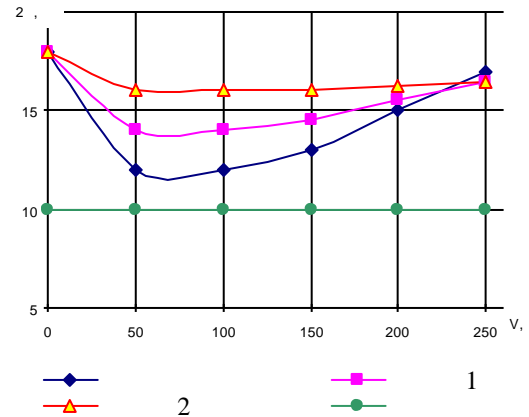
(6)



.4



.5



.5

$14,4 \cdot 10^{-6} \text{ } ^2/ -$
 $96,97 \cdot 10^{-6} \text{ } ^2/ -$
 (6275)
 ;)
 ($1000 / ^3$; $1,01 \cdot 10^{-6} \text{ } ^2/ -$
 $1 (1230 / ^3$; ,
 $2 (1370 / ^3$; ,
)
 ,
 $D=1000$.
 200 , 50
 $50-100$.

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