FREE OSCILLATIONS OF A LARGE AMPLITUDE IN A HEAT RESONATOR

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Nonlinear heat resonator allows one to create the conditions for observations of nonequilibrium structures excited by a source of heat perturbations [1]. The report presents the results of investigation of thermal-acoustical properties of a locally-nonequilibrium heat field in the wide temperature range. Free oscillations of a large amplitude are studied for three principal types of resonators:
the closed-ends resonator [$T(x=0,t)=T_0$, $T(x=h,t)=T_1$; may be $T_0=T_1$],
the open-ends resonator [$q(x=0,t)=q_0$, $q(x=h,t)=q_1$; may be $q_0=q_1$],
the half-open resonator [$q(x=0,t)=q_0$, $T(x=h,t)=T_1$].

The locally nonequilibrium thermal field is governed by the system of equations [1]:

$$c\frac{\partial T}{\partial t}+\frac{\partial q}{\partial x}=0\,,\ \ q+\gamma\frac{\partial q}{\partial t}=-\lambda\frac{\partial T}{\partial x}-\rho\Omega\frac{\partial}{\partial x}\left(\frac{1}{u}\frac{\partial q}{\partial x}\right),\ t\ge 0\,,\ x\in[0,h]\,.$$

Here T is the temperature, q is the specific heat flux, ρ is the mass density, u is the energy density, $c=du/dT$ is the volumetric heat capacity, λ is the thermal conductivity, γ is the relaxation time of heat flux, $w=(\lambda/c\gamma)^{1/2}$ is the velocity of propagation of heat perturbations, x is the space coordinate, t is the time. The factor Ω stands for the artificial dissipation coefficient that is applied to smooth strong discontinuities of the heat field. The initial conditions are as follows: $T(x,t=0)=T^0(x)$, $q(x,t=0)=q^0(x)$. All the listed quantities are dimensionless.

The problem is solved by straight numerical modelling. Here are some of our results for the closed-ends resonator. The basic criteria of the problem are $Q=\dfrac{q\,h}{T_1\,\lambda(T_1)}$; $g=\dfrac{h}{T_1}\dfrac{\partial T}{\partial x}$; energy parameter $E=\dfrac{cT}{\rho w^2}$; nonequilibrium parameter $\Omega^{-2}=\dfrac{q^2}{u^2w^2}$; parameter of medium nonlinearity $D=\dfrac{T}{w^2}\dfrac{d(w^2)}{dT}$; $A_{\mathrm{T}}(x_i,t)=\dfrac{T(x_i,t)}{T^0(x_i)}$; $A_{\mathrm{q}}(x_i,t)=q(x_i,t)$; $x_i=i\,h/6$; $i=0,1,...,6$.

The physical properties of the medium are given by $c\equiv const$, $\gamma\equiv const$, $\lambda=\lambda_0\exp(n_1T)$; λ_0, n_1 are constant.

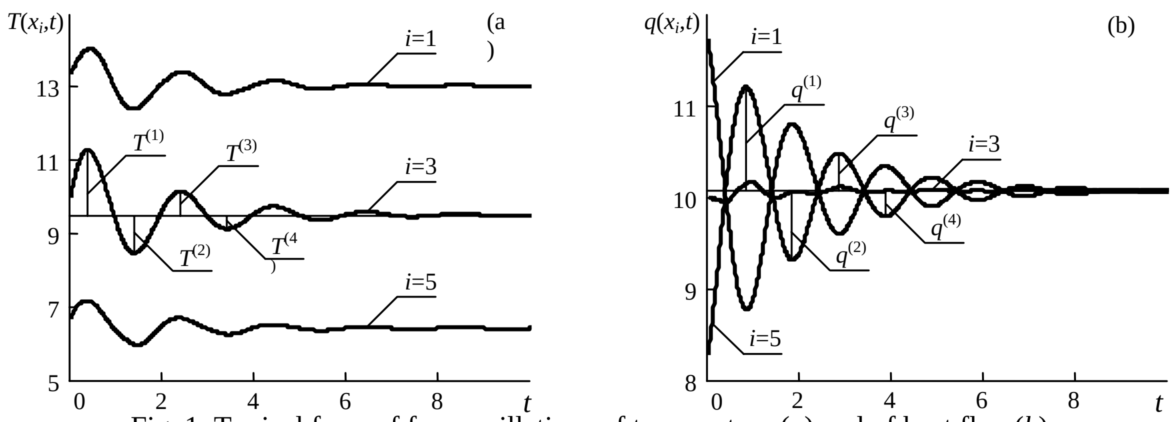

Fig. 1. Typical form of free oscillations of temperature (*a*) and of heat flux (*b*)

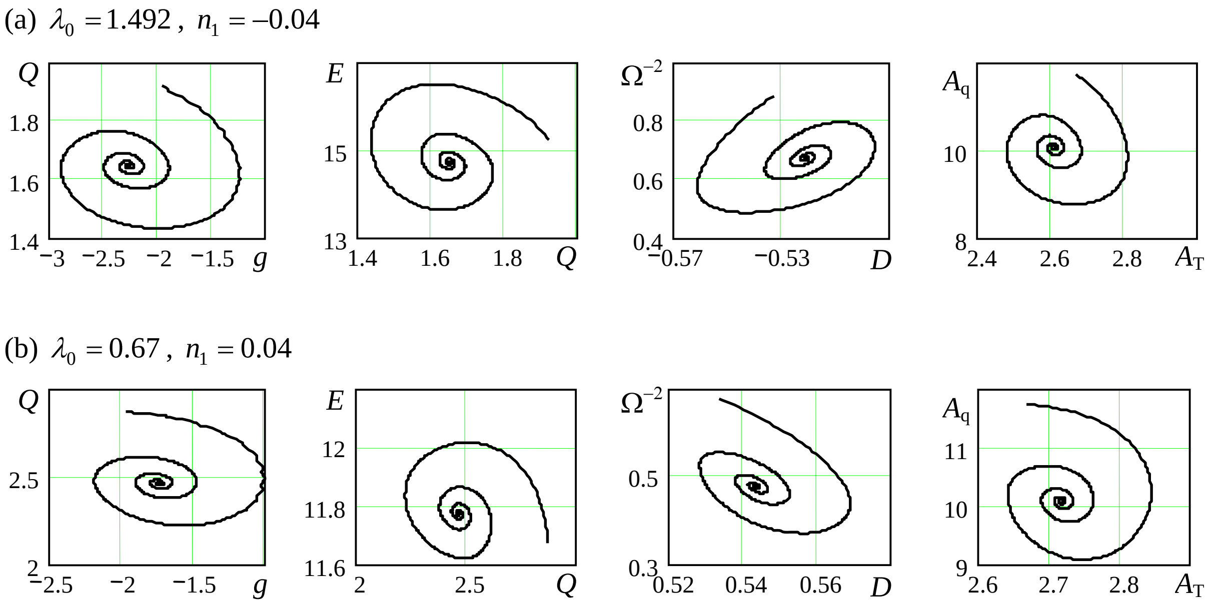

Fig. 2. Phase properties of the free oscillations in the closed-ends resonator

The effect of the parameter of medium nonlinearity on amplitudes of temperature oscillations and heat fluxes oscillations is shown in table 1.

Table 1.

n_1 ($i=1$ / $i=5$)	$T^{(1)}$	$T^{(2)}$	$T^{(3)}$	$T^{(4)}$	$q^{(1)}$	$q^{(2)}$	$q^{(3)}$	$q^{(4)}$
0.1	0.494	0.356	0.188	0.129	1.098	0.583	0.38	0.22
	1.31	0.688	0.495	0.27	1.09	0.728	0.436	0.251
0.08	0.536	0.36	0.2	0.131	1.039	0.586	0.368	0.213
	1.152	0.626	0.437	0.239	1.085	0.674	0.421	0.234
0.06	0.583	0.364	0.212	0.134	1.011	0.605	0.359	0.221
	1.01	0.577	0.377	0.214	1.081	0.648	0.406	0.23
0.04	0.642	0.376	0.231	0.138	1	0.601	0.364	0.211
	0.893	0.531	0.332	0.192	1.092	0.622	0.405	0.217
0.02	0.699	0.405	0.253	0.146	1.045	0.623	0.386	0.219
	0.824	0.501	0.304	0.181	1.097	0.631	0.404	0.221
0	0.795	0.473	0.29	0.17	1.105	0.649	0.407	0.227
	0.798	0.479	0.29	0.171	1.113	0.647	0.409	0.228
-0.02	0.892	0.545	0.329	0.196	1.19	0.679	0.438	0.238
	0.767	0.464	0.284	0.166	1.132	0.682	0.417	0.24
-0.04	1.006	0.642	0.377	0.232	1.314	0.716	0.483	0.254
	0.745	0.453	0.281	0.167	1.149	0.738	0.429	0.259
-0.06	1.135	0.762	0.435	0.279	1.468	0.761	0.537	0.275
	0.745	0.446	0.278	0.171	1.163	0.813	0.443	0.286
-0.08	1.28	0.908	0.505	0.336	1.654	0.809	0.601	0.302
	0.765	0.443	0.276	0.178	1.164	0.911	0.457	0.325
-0.1	1.442	1.078	0.593	0.399	1.862	0.86	0.672	0.335
	0.794	0.449	0.279	0.19	1.157	1.033	0.47	0.373

References

[1] Shablovsky O.N. (2003) Relaxational Heat Transfer in Nonlinear Media. GSTU, Gomel, Belarus.