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Erratum: Optimal behavior of viscoelastic flow at resonant frequencies [Phys. Rev. E 70, 056302 (2004)]

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In this paper, the entropy generation rate in the zero-mean oscillatory flow of a Maxwell fluid in a pipe was calculated under isothermal conditions, using the dimensionless expression,

$$\dot{S}^*(r^*,t^*) = \frac{1}{T^*}\left(\frac{\partial V^*}{\partial r^*}\right)^2. \tag{1}$$

The use of this equation for a Maxwell fluid is incorrect. Equation (1) was obtained by substituting the Newtonian constitutive equation for the stress tensor, that in dimensional terms is given by $\tau = -\eta \nabla \mathbf{v}$, into the general expression for the local entropy production rate,

$$\dot{S} = -\tau : \nabla \mathbf{v}/T. \tag{2}$$

Explicitly, we have

$$\dot{S} = \eta \nabla \mathbf{v} : \nabla \mathbf{v}/T. \tag{3}$$

Notice that the entropy production rate for a Maxwell fluid cannot be obtained by substituting the Maxwellian velocity field in Eq. (3) since this equation is only valid for Newtonian fluids. The correct expression for the entropy production rate in the Maxwellian case has to be derived by considering the constitutive equation for the stress tensor of the Maxwell fluid, namely, $t_m \frac{\partial \tau}{\partial t} = -\eta \nabla \mathbf{v} - \tau$. Expressed in integral form, we have [1],

$$\tau(t) = -\int_{-\infty}^{t} \left[\frac{\eta}{t_m} e^{-(t-t')/t_m}\right] \nabla \mathbf{v}(t') dt'. \tag{4}$$

Then, we substitute Eq. (4) into Eq. (2) in order to obtain the general expression for the entropy production rate for a Maxwellian fluid under isothermal conditions:

$$\dot{S} = \left[-\int_{-\infty}^{t} \left[\frac{\eta}{t_m} e^{-(t-t')/t_m}\right] \nabla \mathbf{v}(t') dt'\right] : [\nabla \mathbf{v}(t)]/T. \tag{5}$$

Explicitly, we need to substitute the velocity profile given by Eq. (1) in the paper, into Eq. (5) and perform the integral of $\dot{S}$ over one period of oscillation. Thus we find the local (time-averaged) entropy generation rate for the Maxwellian fluid in our case, that in dimensionless terms reads

$$\dot{S}^*(r^*) = \frac{1}{1+\omega^*}\frac{1}{T^*}\left(\frac{\partial V^*}{\partial r^*}\right)^2, \tag{6}$$

where $\omega^* = \omega t_m$ is the dimensionless frequency. Note that V and $\dot{S}$ are not in phase, as it was wrongly stated in the paper. In order to get the global entropy generation rate per unit length in the axial direction, we have to integrate Eq. (6) over the tube cross section. In the paper, we stated that while maximum values of the amplitude of the averaged velocity $\langle V^* \rangle$ decrease as higher resonant frequencies are reached, maximum values of the global entropy generation rate $\langle \dot{S}^* \rangle$ remain almost constant (Fig. 1 in the paper). The figure in the present note shows the results obtained with the correct expression (6) for the entropy production rate and the amplitude of the averaged velocity of a Maxwell fluid, as a function of the dimensionless frequency. We observe that, in contrast with the result presented in Fig. 1 of the original paper, maximum values of both $\langle V^* \rangle$ and $\langle \dot{S}^* \rangle$ decrease as higher resonant frequencies are reached.

However, the main conclusion stated in the paper regarding the optimal behavior of the system remains unchanged.

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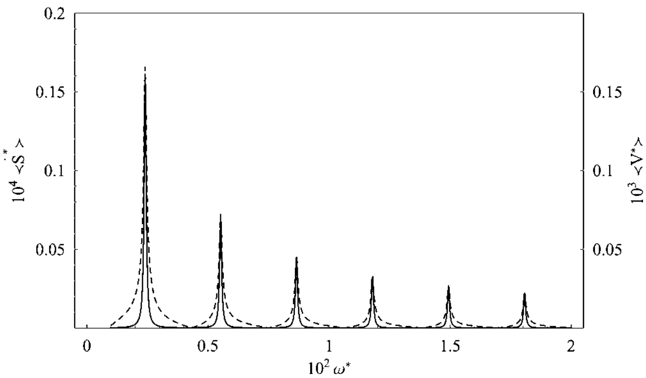

FIG. 1. Amplitude of the dimensionless velocity $\langle V^* \rangle$ (dashed line) and global entropy generation rate $\langle \dot{S}^* \rangle$ (solid line) as functions of the dimensionless frequency ω^* with $\alpha = 0.01$ and under isothermal conditions.

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[1] F. A. Morrison, *Understanding Rheology* (Oxford University Press, New York, 2001).