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Comment on "Effects of thermophoresis and Brownian motion on nanofluid heat transfer and entropy generation" by M. Mahmoodi, Sh. Kandelousi, Journal of Molecular Liquids, 211 (2015) 15–24

Navid Freidoonimehr, Asghar B. Rahimi *

Faculty of Engineering, Ferdowsi University of Mashhad, P.O. Box No. 91775-1111, Mashhad, Iran

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ABSTRACT

This communication concerns some erroneous claims, which arise from significant conceptual and logical flaws in understanding, derivation and discussion in the recent article by M. Mahmoodi and Sh. Kandelousi, Effects of thermophoresis and Brownian motion on nanofluid heat transfer and entropy generation, Journal of Molecular Liquids 211 (2015) 15–21.

1. Introduction

In recent years, the efficiency calculation of the heat exchanger systems was restricted to the first law of thermodynamics in many studies. In many industrial systems, various mechanisms that account for irreversibility compete with each other. Hereupon, thermodynamic optimization has became the concern of several researchers in recent years and also is the condition of the most desirable trade-off between two or more competing irreversibility [1]. Entropy generation minimization has been comprehensively covered by Bejan [2] specifically, in the fields of refrigeration, heat transfer, storage, solar thermal power conversion, and thermal science education. Entropy generation minimization method is employed to optimize the thermal engineering devices for higher energy efficiency. In order to access the best design of thermal systems, one can employ the second law of thermodynamics by minimizing the irreversibility [3,4]. The performance of an engineering equipment in the presence of the irreversibilities is reduced and entropy generation function is a measure of the level of the available irreversibilities in a process. Since the entropy generation is the criteria for measurement of the available work destruction of the systems, reduction of the entropy generation is essential to obtain optimal design of energy systems [5]. Moreover, entropy generation causes systems to decrease the useful power cycle outputs for a power production device or increase the power input to the cycle for power consumption devices. It is important to emphasize that the second law of thermodynamics is more reliable than the first law of thermodynamics analysis, because of the limitation of the first law efficiency in the heat transfer engineering systems [6]. The evaluation of the entropy generation is done to improve the system performance. In addition, heat transfer, mass transfer, viscous dissipation, finite temperature gradients, etc. can be used as the sources of entropy generation [7].

In recent decades, many researchers have been motivated to conduct the applications of the second law of thermodynamics in the design of thermal engineering systems. Rashidi et al. [8] studied the first and second law analyses of an electrically conducting fluid past a rotating disk in the presence of a uniform vertical magnetic field analytically and then applied Artificial Neural Network and Particle Swarm Optimization algorithm to minimize the entropy generation. In another study, Rashidi et al. [9] investigated the analysis of the second law of thermodynamics applied to an electrically conducting incompressible nano-fluid flowing over a porous rotating disk. Abolbashari et al. [10] employed homotopy analysis method (HAM) to study the entropy analysis in an unsteady magneto-hydrodynamic nano-fluid regime adjacent to an accelerating stretching permeable surface. Jafari and Freidoonimehr [11] studied the second law of thermodynamics over a stretching permeable surface in the presence of the uniform vertical magnetic field in the slip nano-fluid regime. Moreover, Rashidi et al. [12] performed the second law of thermodynamics analysis of a rotating porous disk in the presence of a magnetic field with temperature-dependent thermo-physical properties numerically using fourth-order Runge–Kutta method.

* Corresponding author.
E-mail address: rahimiab@um.ac.ir (A.B. Rahimi).

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2. Problem statement

In a recent paper published in this journal [13], the entropy generation of kerosene–alumina nanofluid in a channel with thermal radiation was studied. Unfortunately, the entropy generation equation, which they have obtained, has two important mistakes. First, they have considered the effect of thermal radiation in their analysis which appeared in the energy equation using the Rosseland approximation. This effect must also be considered in the entropy generation equation, specifically in the irreversibility part caused by the heat transfer. The authors did not consider this significant effect in their analysis. The second problem is that by considering the effect of nanoparticles diffusion in the form of concentration equation, one of the governing equations, the authors must consider this effect as one of the main effects in the entropy generation equation in the form of diffusive irreversibility effect. This substantial effect was also ignored.

In this paper, we obtain the correct form of entropy generation equation and then present the entropy generation results in the valid form. Apart from the mistakes mentioned above, the second part of the entropy generation equation, which is related to the irreversibility due to viscous dissipation, (Eq. (14) Ref. [13]) was incorrect. The viscous dissipation function, written in the brackets, was typed wrongly and also the physical parameter k, thermal conductivity, multiplied to these brackets must be μ, dynamic viscosity, instead.

According to [2,14–18], the rate of local entropy generation of the kerosene–alumina nanofluid between two horizontal parallel plates considering the thermal radiation and diffusion effects, after applying the boundary layer and Rosseland approximations, can be described as

$$\dot{S}'''_{gen} = \underbrace{\frac{k}{T_m^2}\left[\left(\frac{\partial T}{\partial y}\right)^2 + \frac{16\sigma_e T_c^3}{3\beta_R k}\left(\frac{\partial T}{\partial y}\right)^2\right]}_{\text{Heat Transfer Irreversibility}} + \underbrace{\frac{\mu}{T_m}\left\{2\left[\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial y}\right)^2\right] + \left(\frac{\partial u}{\partial y}\right)^2\right\}}_{\text{Fluid Friction Irreversibility}} + \underbrace{\frac{RD}{C_m}\left[\left(\frac{\partial C}{\partial y}\right)^2\right] + \frac{RD}{T_m}\left[\left(\frac{\partial T}{\partial y}\right)\left(\frac{\partial C}{\partial y}\right)\right]}_{\text{Diffusive Irreversibility}}, \quad (1)$$

The above equation reveals that the entropy generation is due to the following three effects: the first effect, a conduction effect, is the entropy generation due to heat transfer across a finite temperature difference as well as thermal radiation (Heat Transfer Irreversibility, HTI); the second effect is due to Fluid Friction Irreversibility (FFI), and the third effect is due to diffusion (Diffusive Irreversibility, DI). It must be noted that the entropy generation due to diffusion is the sum of a crossed term with both thermal and concentration gradients and a pure term which involves concentration gradient only. The entropy generation number, dimensionless form of entropy generation rate, represents the ratio between the actual entropy generation rate ($\dot{S}'''_{gen}$) and the characteristic entropy generation rate ($\dot{S}'''_0$). The similarity transformation parameters

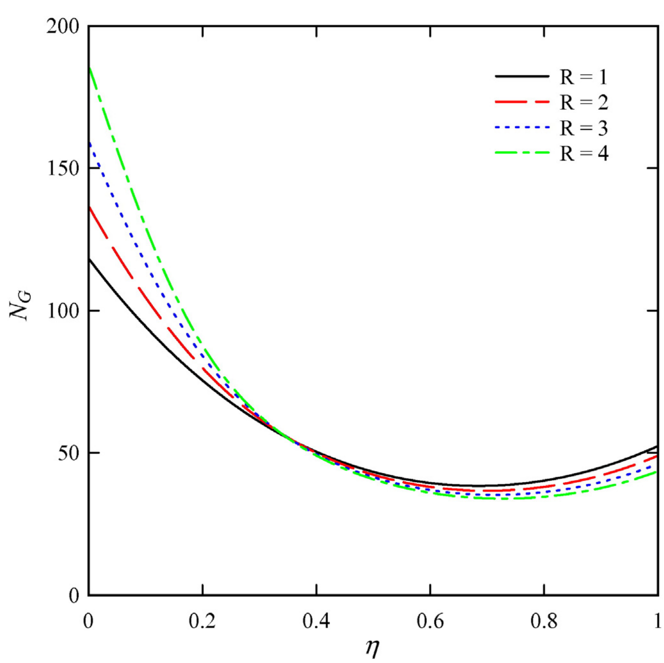

Fig. 1. Effect of viscosity parameter on the entropy generation number when $Ec = 0.04$, $Rd = 1$, $Nt = 0.1$, $Nb = 0.1$, $Sc = 0.1$, and $Pr = 25$.

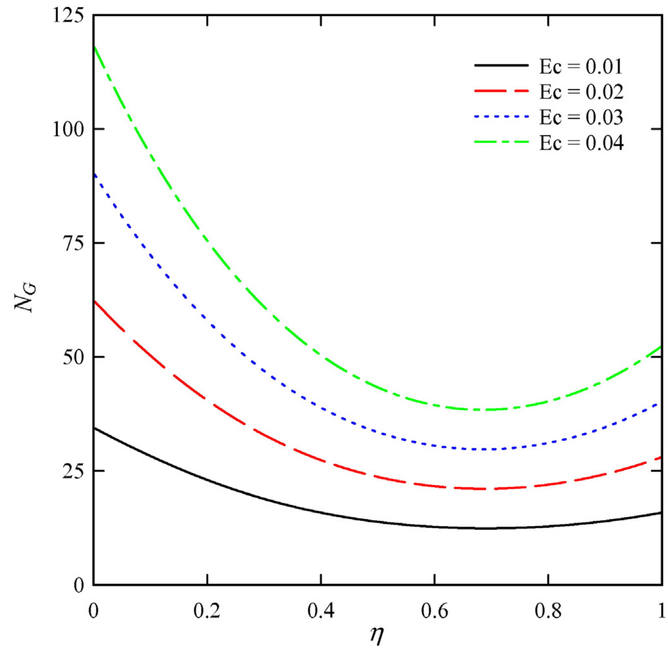

Fig. 2. Effect of Eckert number on the entropy generation number when $Rd = 1$, $Nt = 0.1$, $Nb = 0.1$, $Sc = 0.1$, $R = 1$, and $Pr = 25$.

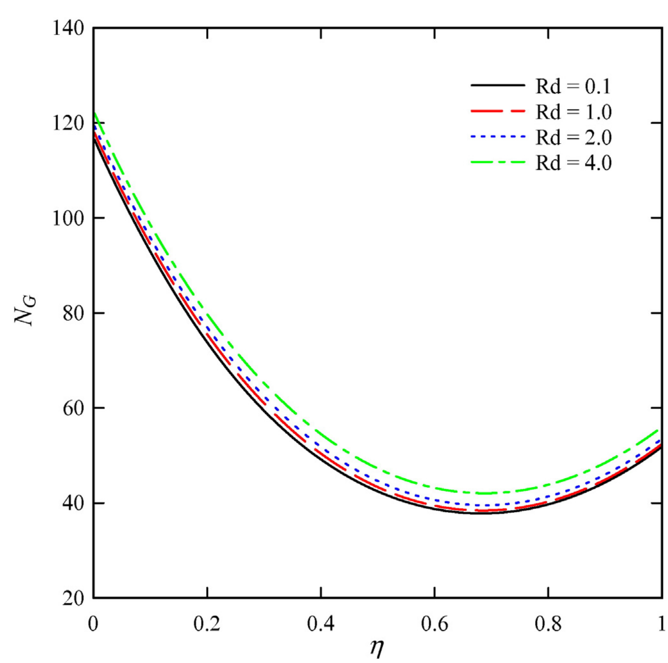

Fig. 3. Effect of radiation parameter on the entropy generation number when $Ec = 0.04$, $Nt = 0.1$, $Nb = 0.1$, $Sc = 0.1$, $R = 1$, and $Pr = 25$.

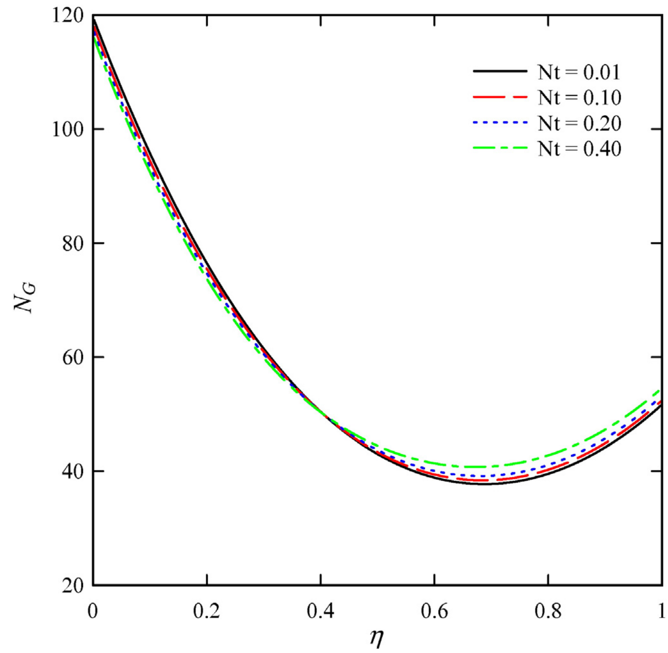

Fig. 4. Effect of thermophoretic parameter on the entropy generation number when $Ec = 0.04$, $Rd = 1$, $Nb = 0.1$, $Sc = 0.1$, $R = 1$, and $Pr = 25$.

of Eq. (7) of [13] are employed to non-dimensionalize the local entropy generation. Thus, the entropy generation number (N_G) becomes:

$$N_G = \frac{\dot{S}'''_{gen}}{\dot{S}'''_0} = \left(1 + \frac{4}{3}R_d\right)\theta'^2(\eta) + \frac{PrEc}{\Omega}\left(4f'^2(\eta) + Xf''^2(\eta)\right) + \lambda\left(\frac{S}{\Omega}\right)^2\phi'^2(\eta) + \lambda\left(\frac{S}{\Omega}\right)\theta'(\eta)\phi'(\eta), \tag{2}$$

where $\dot{S}'''_0 = k(\Delta T)^2/h^2T_m^2$ is the characteristic entropy generation rate, $R_d = 4\sigma_e T_c^3/\beta_R k$ is the radiation parameter, $Pr = \nu/\alpha$ is the Prandtl number, $Ec = \rho a^2 h^2/(\rho c_p)_f \Delta T$ is the Eckert number, $\Omega = \Delta T/T_m$ and $\varsigma = \Delta C/C_m$ are the dimensionless temperature and concentration differences, respectively, and $X = x/h$ is the dimensionless axial coordinate, and $\lambda = RDC_m/k$ is the diffusive constant parameter.

Finally, it is worth mentioning that Mahmoodi and Kandelousi [13] considered the entropy generation equation in the form of:

$$\dot{S}'''_{gen} = \frac{k}{T_m^2}\left[\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial y}\right)^2\right] + \frac{k}{T_m}\left\{2\left(\frac{\partial u}{\partial x}\right)^2 + 2\left(\frac{\partial v}{\partial y}\right)^2 + \left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right)\right\}. \tag{3}$$

As it is mentioned above, there are some major and minor problems in the above equation. In summary, the authors forgot to consider the effects of irreversibilities caused by thermal radiation and nanoparticles diffusion in the entropy generation equation. Furthermore, in the viscous dissipation part of entropy generation equation, the coefficient that multiplied the braces must be μ instead of k and also the third term in the viscous dissipation part is incorrect and must exponentiate by two.

In the next step, we solve the entropy generation number equation in order to evaluate the effect of its different involving physical parameters in correct form based on correct entropy generation equation. Considering the two forgotten effects will completely influence the results because of their direct roles in the entropy generation equation. So, it is clear that this leads to have correct and better understandings about the effects of different involving physical parameters on the entropy generation. Figs. 1–5 present the effects of viscosity parameter, Eckert number, radiation parameter, thermophoretic parameter, and Brownian parameter on the entropy generation number in their correct format. The information in these figures which are in the non-dimensional form should be substituted, respectively, for incorrect information in Figs. 3(d), 4(c), 5(c), 6(c), and 7(c) of Ref. [13].

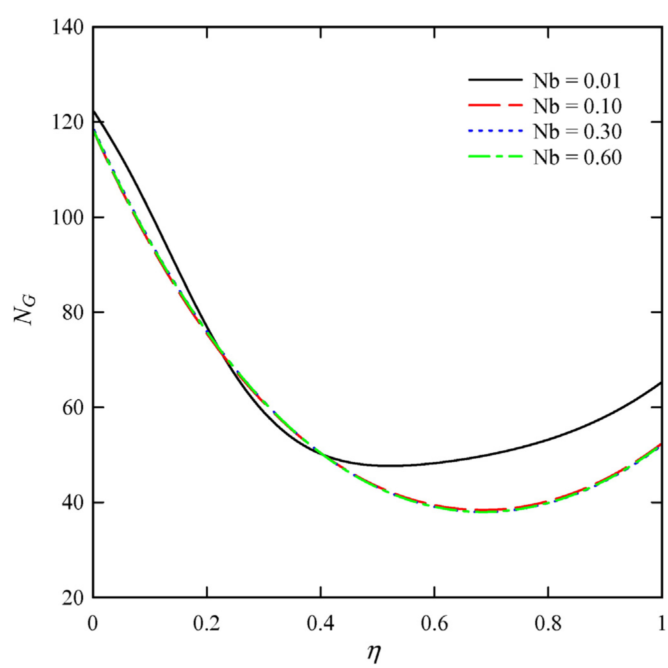

Fig. 5. Effect of Brownian parameter on the entropy generation number when $Ec = 0.04$, $Rd = 1$, $Nt = 0.1$, $Sc = 0.1$, $R = 1$, and $Pr = 25$.

3. Conclusions

The important existing mistakes in the previous published paper in this Journal have been discussed here and the correct forms of the relevant results presented. As it was mentioned, the authors have missed to consider the effects of thermal radiation and nanoparticles diffusion in the entropy generation equation which caused obtaining wrong results. The entropy generation results considering these two important effects have been depicted in this paper which now can be reliable. For example, as it is expected, increasing Eckert number and thermal radiation lead to enhancement of the entropy generation number because of the direct role of these parameters in the entropy generation equation. These effects were not observed in the presented results of Ref. [13]. Therefore, the information in Figs. 1–5 in this paper which are in the non-dimensional form should be substituted, respectively, for incorrect information in Figs. 3(d), 4(c), 5(c), 6(c), and 7(c) of Ref. [13].

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