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Effect of variable thermophysical properties on laminar free convection of polyatomic gas

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Abstract—The present work deals with free convection of polyatomic gas, for which the thermal conductivity, viscosity and specific heat are assumed to vary with absolute temperature according to a simple power law, the density is taken as inversely proportional to absolute temperature at constant pressure, while the Prandtl number is assumed constant. The energy equation is so revised as to consider the variation of the specific heat with temperature, and the governing partial equations for laminar free convection of the polyatomic gases are treated as dimensionless ordinary equations by similarity transformation. The numerical results are given and are well discussed.

1. INTRODUCTION

THE EFFECT of the variable fluid properties on laminar free convection heat transfer of monoatomic gas, biatomic gas, air and water vapour along an isothermal vertical flat plate has been reported in a previous paper [1], in which the temperature parameters are used to describe the change of viscosity and thermal conductivity with temperature according to a simple power law, respectively, the density is taken as inversely proportional to thermodynamic temperature at constant pressure, while the Prandtl number is assumed constant. However, the variation of specific heat with temperature is more obvious for the polyatomic gases. Hence, it is necessary to consider also the effect of variable specific heat on the laminar free convection of polyatomic gases. The present work deals with such a variation of specific heat with temperature further as $c \sim T^{n_{c_p}}$ for analysing laminar free convection of the polyatomic gases.

2. BASIC CONSIDERATION OF THE VARIABLE PROPERTIES

The thermodynamic temperature of the gas far away from the wall, T_∞, could be taken as the reference temperature, T_0, for free convection analysis. As in ref. [1], the variations of μ, λ, ρ and ν with thermodynamic temperature for the polyatomic gases can be expressed as follows:

$$\mu/\mu_\infty = (T/T_\infty)^{n_\mu} \tag{1}$$

$$\lambda/\lambda_\infty = (T/T_\infty)^{n_\lambda} \tag{2}$$

$$\rho/\rho_\infty = (T/T_\infty)^{-1} \tag{3}$$

$$\nu/\nu_\infty = (T/T_\infty)^{n_\mu+1}. \tag{4}$$

In addition, we further assume

$$c_p/c_{p_\infty} = (T/T_\infty)^{n_{c_p}}. \tag{5}$$

According to the summarized experimental value of μ, λ and c_p for several polyatomic gases reported in refs. [2–5], n_μ, n_λ, n_{c_p} and the deviations of μ, λ and c_p therefore arising from the corresponding experimental data are listed in Table 1.

3. GOVERNING EQUATION

The analytical model and coordinating system used for free convection of gas along an isothermal vertical flat plate is shown in Fig. 1. The boundary layer is laminar when Ra ($=Gr\,Pr$) is less than 10^9 [6].

The conservation equations of mass, momentum and energy for steady laminar free convection in a boundary layer for the polyatomic gas are as follows:

$$\frac{\partial}{\partial x}(\rho w_x)+\frac{\partial}{\partial y}(\rho w_y) = 0 \tag{6}$$

$$\rho\left(w_x\frac{\partial w_x}{\partial x}+w_y\frac{\partial w_x}{\partial y}\right) = \frac{\partial}{\partial y}\left(\mu\frac{\partial w_x}{\partial y}\right)+\rho g\frac{T-T_\infty}{T_\infty} \tag{7}$$

$$\rho\left(w_x\frac{\partial(c_pT)}{\partial x}+w_y\frac{\partial(c_pT)}{\partial y}\right) = \frac{\partial}{\partial y}\left(\lambda\frac{\partial T}{\partial y}\right). \tag{8}$$

The boundary conditions are

$$y=0,\quad w_x=0,\quad w_y=0,\quad T=T_w \tag{9}$$

$$y\to\infty,\quad w_x\to 0,\quad T\to T_\infty. \tag{10}$$

As in ref. [1], the partial differential equations (6)–

NOMENCLATURE

- a diffusivity [$m^2\ s^{-1}$]
- c_p specific heat at constant pressure [$J\ kg^{-1}\ K^{-1}$]
- g gravitational acceleration [$m\ s^{-2}$]
- $Gr_{x,\infty}$ local Grashof number, $gx^3(T_w/T_\infty-1)/\nu_\infty^2$
- n_{c_p} temperature exponent for specific heat
- n_μ temperature exponent for dynamic viscosity of gas
- n_λ temperature exponent for thermal conductivity of gas
- p pressure [$N\ m^{-2}$]
- Pr Prandtl number, $\mu c_p/\lambda$
- q_x local heat transfer rate per unit area from wall to fluid [$W\ m^{-2}$]
- T absolute temperature [K]
- w_x velocity component in the x-direction [$m\ s^{-1}$]
- w_y velocity component in the y-direction [$m\ s^{-1}$]
- W_x dimensionless velocity component in the x-direction
- W_y dimensionless velocity component in the y-direction.

Greek symbols

- α local heat transfer coefficient [$W\ m^{-2}\ K^{-1}$]
- δ boundary-layer thickness [m]
- θ dimensionless temperature, $(T-T_\infty)/(T_w-T_\infty)$
- λ thermal conductivity [$W\ m^{-1}\ K^{-1}$]
- μ absolute viscosity [$kg\ m^{-1}\ s^{-1}$]
- ν kinematic viscosity, μ/ρ [$m^2\ s^{-1}$]
- ρ density [$kg\ m^{-3}$].

Subscripts

- w at wall
- ∞ far from the wall surface.

(8) can be transformed to the corresponding dimensionless ordinary differential equations by the following similarity transformation:

$$\eta=\frac{y}{x}\frac{(Gr_{x,\infty})^{1/4}}{\sqrt{2}} \tag{11}$$

$$\theta=\frac{T-T_\infty}{T_w-T_\infty} \tag{12}$$

$$W_x=[2\sqrt{(gx)}(T_w/T_\infty-1)^{1/2}]^{-1}w_x \tag{13}$$

$$W_y=[2\sqrt{(gx)}(T_w/T_\infty-1)^{1/2}(\tfrac{1}{4}Gr_{x,\infty})^{-1/4}]^{-1}w_y. \tag{14}$$

Then, equations (6)–(8) are transformed to dimensionless ordinary differential equations as follows:

$$2W_x-\eta\frac{dW_x}{d\eta}+4\frac{dW_y}{d\eta}-\frac{1}{\rho}\frac{d\rho}{d\eta}(\eta W_x-4W_y)=0 \tag{15}$$

$$\frac{\nu_\infty}{\nu}\left[W_x\left(2W_x-\eta\frac{dW_x}{d\eta}\right)+4W_y\frac{dW_x}{d\eta}\right]=\frac{d^2W_x}{d\eta^2}+\frac{1}{\mu}\frac{d\mu}{d\eta}\frac{dW_x}{d\eta}+\frac{\nu_\infty}{\nu}\theta \tag{16}$$

$$Pr\frac{\nu_\infty}{\nu}\left[(-\eta W_x+4W_y)\frac{d\theta}{d\eta}+(-\eta W_x+4W_y)\left(\theta+\frac{T_\infty}{T_w-T_\infty}\right)\frac{1}{c_p}\frac{dc_p}{d\eta}\right]=\frac{d^2\theta}{d\eta^2}+\frac{1}{\lambda}\frac{d\lambda}{d\eta}\frac{d\theta}{d\eta} \tag{17}$$

with the corresponding boundary conditions

$$\eta=0,\quad W_x=0,\quad W_y=0,\quad \theta=1 \tag{18}$$

$$\eta\to\infty,\quad W_x\to 0,\quad \theta\to 0. \tag{19}$$

Combined with equations (5) and (12), equation (17) is transformed to

$$(1+n_{c_p})Pr\frac{\nu_\infty}{\nu}(-\eta W_x+4W_y)\frac{d\theta}{d\eta}=\frac{d^2\theta}{d\eta^2}+\frac{1}{\lambda}\frac{d\lambda}{d\eta}\frac{d\theta}{d\eta}. \tag{20}$$

From equations (1)–(4) combined with equation (12), we have

$$\frac{1}{\rho}\frac{d\rho}{d\eta}=-\frac{(T_w/T_\infty-1)\frac{d\theta}{d\eta}}{(T_w/T_\infty-1)\theta+1} \tag{21}$$

$$\frac{1}{\mu}\frac{d\mu}{d\eta}=\frac{n_\mu(T_w/T_\infty-1)\frac{d\theta}{d\eta}}{(T_w/T_\infty-1)\theta+1} \tag{22}$$

$$\frac{1}{\lambda}\frac{d\lambda}{d\eta}=\frac{n_\lambda(T_w/T_\infty-1)\frac{d\theta}{d\eta}}{(T_w/T_\infty-1)\theta+1} \tag{23}$$

$$\frac{\nu_\infty}{\nu}=\left[\frac{1}{(T_w/T_\infty-1)\theta+1}\right]^{n_\mu+1}. \tag{24}$$

4. HEAT TRANSFER ANALYSIS

The local Nusselt number $Nu_{x,\infty}$ can be expressed as follows [1]:

Table 1. The values of n_μ, n_λ and n_{c_p} from experimental data of μ, λ and c_p with deviation

Gas	T_0 (K)	Data source	n_μ	Temperature range (K)	Percentage deviation (%)	n_λ	Temperature range (K)	Percentage deviation (%)	n_{c_p}	Temperature range (K)	Percentage deviation (%)
Gas mixture†	273	[5]	0.75	273–1173	±3	1.02	273–1473	±1	0.134	273–1473	±2.5
CO_2	273		0.88	220–700	±2	1.3	220–720	±2	0.34	230–810	±1
C_2H_6	273		0.853	210–900	±3	1.71	220–600	±3	0.73	273–922	±1.5
CH_4	273	[2–4]	0.78	220–1000	±3	1.29	230–1000	±3.6	0.534	273–1033	±4.2
CCl_4	273		0.912	270–500	±1	1.29	260–400	±1	0.28	230–700	±2
SO_2	273		0.91	200–1250	±4	1.323	250–900	±4.5	0.257	273–1200	±3
H_2S	273		1	270–500	±1	1.29	260–400	±1	0.18	230–700	±2
NH_3	273		1.04	220–1000	±1	1.375	250–900	±2	0.34	230–1033	±0.36
C_2H_5OH	273		0.925	270–600	±0.6	1.95	260–430	±4	0.59	250–922	±0.25

† Components of the gas mixture: CO_2 = 0.13, water vapour = 0.11 and N_2 = 0.76.

$$Nu_{x,\infty} = -(T_w/T_\infty)^{n_\lambda}(\tfrac{1}{4}Gr_{x,\infty})^{1/4}\left.\frac{d\theta}{d\eta}\right|_{\eta=0}. \quad (25)$$

The velocity and temperature fields can be solved from equations (15), (16) and (20) with boundary conditions, equations (18) and (19), combined with equations (21)–(24), and so, we can obtain $Nu_{x,\infty}$ from equation (25). It will be expected that, for the case of variable properties, the dimensionless velocity field and the dimensionless temperature field could depend on Pr, n_μ, n_λ, n_{c_p} and (T_w/T_∞).

The calculations were carried out numerically by the shooting method [7]. The typical results for the velocity and temperature field are plotted in Figs. 2–5, and the solutions $(d\theta/d\eta)_{\eta=0}$ at various temperature ratios T_w/T_∞ for several polyatomic gases are shown in Table 2.

Using the curve matching method, we have

$$-\left.\frac{d\theta}{d\eta}\right|_{\eta=0} = (1+0.3n_{c_p})\psi(Pr)\left(\frac{T_w}{T_\infty}\right)^{-m} \quad (26)$$

where

$$\psi(Pr) = 0.567+0.186\ln Pr \quad (27)$$

$$m = 0.35n_\lambda+0.29n_\mu+0.36, \quad \text{for} \quad T_w/T_\infty > 1 \quad (28)$$

$$m = 0.42n_\lambda+0.34n_\mu+0.28, \quad \text{for} \quad T_w/T_\infty < 1. \quad (29)$$

Hence, equation (25) can be rewritten as

$$Nu_{x,\infty} = (1+0.3n_{c_p})\frac{\psi(Pr)}{\sqrt{2}}(Gr_{x,\infty})^{1/4}(T_w/T_\infty)^{n_\lambda-m}. \quad (30)$$

The results predicted by equation (26) are compared with those of the numerical solution from equations (15), (16), (20), (18), (19) and (21)–(24), as shown in Table 2. The agreement is also pretty good.

5. DISCUSSION

Introducing $Nu_{x,w} = d_x x/\lambda_w$ and $Gr_{x,w} = gx^3(T_w/T_\infty - 1)/v_w^2$, we have

$$Nu_{x,w} = \frac{1+0.3n_{c_p}}{\sqrt{2}}\psi(Pr)(Gr_{x,w})^{1/4}(T_w/T_\infty)^{(n_\mu+1)/2-m}. \quad (31)$$

For the biatomic gases, air and water vapour, if the variation of c_p with temperature is taken into consideration, the calculated results of $-(d\theta/d\eta)_{\eta=0}$ from equations (15), (16) and (20) combined with equations (18), (19) and (21)–(24) are listed in Table 3. The corresponding results calculated by equation (26) with equations (27)–(29) are also enclosed in Table 3. The coincidence is very good. So expressions (30) and (31) in this paper, which originate

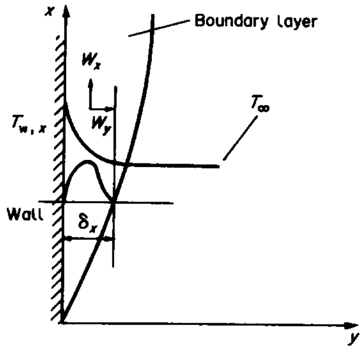

FIG. 1. Physical model coordinate system.

from equation (26), are suitable not only for the polyatomic gases but also all gases.

By comparing the numerical solutions in Table 3 with that in Table 2 of our previous paper [1] it is clear that the calculated results by ignoring variation of c_p with temperature for the biatomic gases, air and water vapour are of very good coincidence.

For gases, if $T_w/T_\infty \to 1$ and $n_{c_p} \to 0$, combined with equations (21)–(24) the governing ordinary differential equations (15), (16) and (20) would be simplified to the following ones:

$$2W_x - \eta\frac{dW_x}{d\eta} + 4\frac{dW_y}{d\eta} = 0 \tag{32}$$

$$W_x\left(2W_x - \eta\frac{dW_x}{d\eta}\right) + 4W_y\frac{dW_x}{d\eta} = \frac{d^2W_x}{d\eta^2} + \theta \tag{33}$$

$$Pr(-\eta W_x + 4W_y)\frac{d\theta}{d\eta} = \frac{d^2\theta}{d\eta^2}. \tag{34}$$

Then equations (26), (30) and (31) would be respectively simplified to

$$-\left.\frac{d\theta}{d\eta}\right|_{\eta=0} = \psi(Pr) \tag{35}$$

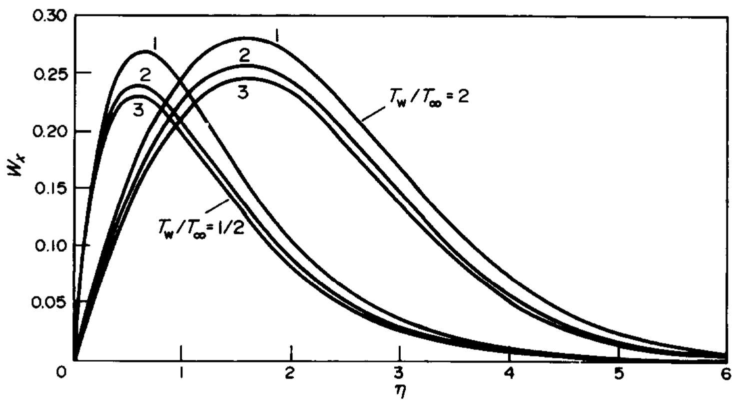

FIG. 2. Comparison of velocity profiles for free convection of different polyatomic gases: 1, gas mixture ($CO_2 = 0.13$, $H_2O = 0.11$, $N_2 = 0.76$); 2, SO_2; 3, NH_3.

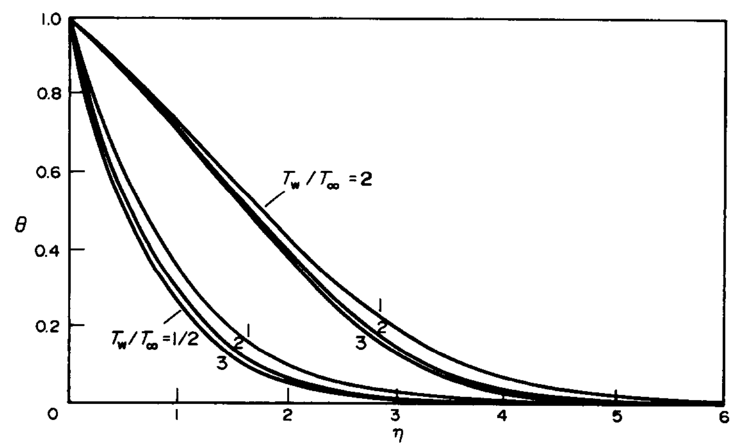

FIG. 3. Comparison of temperature profiles for free convection of different polyatomic gases: 1, gas mixture ($CO_2 = 0.13$, $H_2O = 0.11$, $N_2 = 0.76$); 2, SO_2; 3, NH_3.

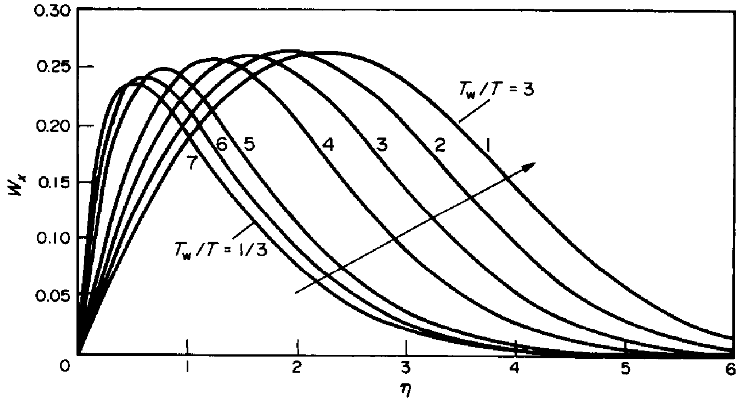

FIG. 4. Comparison of velocity profiles for free convection of CO_2 with different T_w/T_∞: 1, $T_w/T_\infty = 3$; 2, $T_w/T_\infty = 5/2$; 3, $T_w/T_\infty = 2$; 4, $T_w/T_\infty = 3/2$; 5, $T_w/T_\infty = 3/4$; 6, $T_w/T_\infty = 1/2$; 7, $T_w/T_\infty = 1/3$.

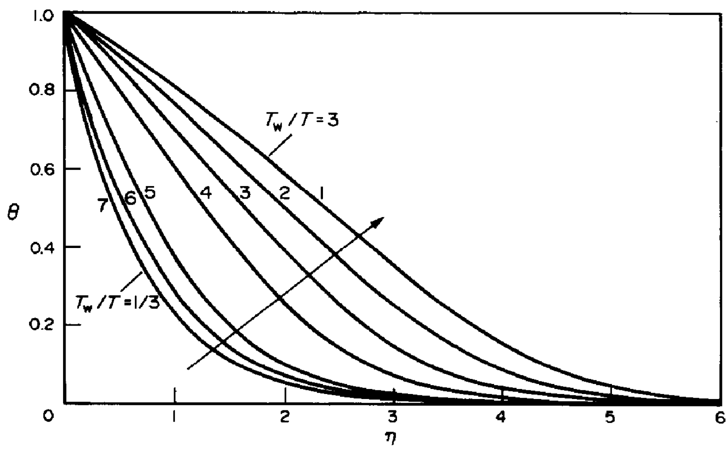

FIG. 5. Comparison of temperature profiles for free convection of CO_2 with different T_w/T_∞: 1, $T_w/T_\infty = 3$; 2, $T_w/T_\infty = 5/2$; 3, $T_w/T_\infty = 2$; 4, $T_w/T_\infty = 3/2$; 5, $T_w/T_\infty = 3/4$; 6, $T_w/T_\infty = 1/2$; 7, $T_w/T_\infty = 1/3$.

Table 2. Calculated results of $-\mathrm{d}\theta/\mathrm{d}\eta|_{\eta=0}$: (1) numerical solution of governing equations (15), (16) and (20) with equations (18), (19) and (21)–(24); (2) from equation (26) with equation (28); (3) from equation (26) with equation (29)

T_w/T_∞	Gas mixture† $Pr = 0.63$ $n_\mu = 0.75$ $n_\lambda = 1.02$ $n_{c_p} = 0.134$	CO_2 $Pr = 0.73$ $n_\mu = 0.88$ $n_\lambda = 1.3$ $n_{c_p} = 0.34$	CH_4 $Pr = 0.74$ $n_\mu = 0.78$ $n_\lambda = 1.29$ $n_{c_p} = 0.534$	CCl_4 $Pr = 0.8$ $n_\mu = 0.912$ $n_\lambda = 1.29$ $n_{c_p} = 0.28$	SO_2 $Pr = 0.81$ $n_\mu = 0.91$ $n_\lambda = 1.323$ $n_{c_p} = 0.257$	H_2S $Pr = 0.85$ $n_\mu = 1$ $n_\lambda = 1.29$ $n_{c_p} = 0.18$	NH_3 $Pr = 0.87$ $n_\mu = 1.04$ $n_\lambda = 1.375$ $n_{c_p} = 0.34$
3 (1)	0.1805	0.1744	0.1908	0.1760	0.1736	0.1696	0.1709
(2)	0.1792	0.1729	0.1896	0.1747	0.1722	0.1687	0.1699
5/2 (1)	0.2136	0.2107	0.2289	0.2130	0.2104	0.2064	0.2093
(2)	0.2125	0.2102	0.2291	0.2125	0.2100	0.2062	0.2093
2 (1)	0.2626	0.2664	0.2870	0.2696	0.2669	0.2630	0.2690
(2)	0.2618	0.2669	0.2880	0.2702	0.2676	0.2637	0.2700
3/2 (1)	0.3435	0.3619	0.3860	0.3670	0.3644	0.3609	0.3733
(2)	0.3426	0.3631	0.3892	0.3682	0.3659	0.3620	0.3752
5/4 (1)	0.4076	0.4408	0.4674	0.4475	0.4452	0.4419	0.4608
(2)	0.4062	0.4413	0.4703	0.4480	0.4461	0.4425	0.4621
3/4 (1)	0.6613	0.7751	0.8095	0.7783	0.7902	0.7873	0.8415
(3)	0.6602	0.7745	0.8105	0.7889	0.7903	0.7903	0.8448
1/2 (1)	0.9752	1.2291	1.2700	1.2504	1.2625	1.2582	1.3751
(3)	0.9757	1.2223	1.2594	1.2483	1.2573	1.2658	1.3805
1/3 (1)	1.4434	1.9722	2.0185	2.0057	2.0429	2.0308	2.2802
(3)	1.4420	1.9289	1.9569	1.9753	2.0001	2.0274	2.2558

† Components of the gas mixture: $CO_2 = 0.13$, water vapour $= 0.11$ and $N_2 = 0.76$.

Table 3. Calculated results of $-\mathrm{d}\theta/\mathrm{d}\eta|_{\eta=0}$: (1) numerical solutions of governing equations (15), (16) and (20) with equations (18), (19) and (21)–(24); (2) from equation (26) with equation (28); (3) from equation (26) with equation (29)

T_w/T_∞	H_2 $Pr = 0.68$ $n_\mu = 0.68$ $n_\lambda = 0.8$ $n_{c_p} = 0.042$	Air $Pr = 0.7$ $n_\mu = 0.68$ $n_\lambda = 0.81$ $n_{c_p} = 0.078$	N_2 $Pr = 0.71$ $n_\mu = 0.67$ $n_\lambda = 0.76$ $n_{c_p} = 0.07$	CO $Pr = 0.72$ $n_\mu = 0.71$ $n_\lambda = 0.83$ $n_{c_p} = 0.068$	O_2 $Pr = 0.733$ $n_\mu = 0.694$ $n_\lambda = 0.86$ $n_{c_p} = 0.108$	Water vapour $Pr = 1$ $n_\mu = 1.04$ $n_\lambda = 1.185$ $n_{c_p} = 0.003$
3 (1)	0.2004	0.2042	0.2094	0.2020	0.2047	0.1740
(2)	0.1999	0.2035	0.2087	0.2015	0.2039	0.1739
5/2 (1)	0.2334	0.2380	0.2433	0.2362	0.2394	0.2113
(2)	0.2329	0.2372	0.2423	0.2355	0.2386	0.2117
2 (1)	0.2814	0.2871	0.2923	0.2859	0.2901	0.2682
(2)	0.2807	0.2861	0.2910	0.2851	0.2892	0.2691
3/2 (1)	0.3579	0.3655	0.3699	0.3656	0.3716	0.3655
(2)	0.3572	0.3644	0.3685	0.3648	0.3706	0.3668
5/4 (1)	0.4167	0.4258	0.4292	0.4272	0.4348	0.4453
(2)	0.4167	0.4247	0.4279	0.4262	0.4337	0.4463
3/4 (1)	0.6370	0.6525	0.6492	0.6601	0.6751	0.7783
(3)	0.6399	0.6546	0.6519	0.6630	0.6766	0.7858
1/2 (1)	0.8906	0.9141	0.8992	0.9311	0.9569	1.2194
(3)	0.9022	0.9245	0.9116	0.9435	0.9656	1.2432
1/3 (1)	1.2431	1.2789	1.2420	1.3116	1.3560	1.9208
(3)	1.2720	1.3056	1.2748	1.3426	1.3781	1.9667

$$Nu_{x,\infty} = \frac{\psi(Pr)}{\sqrt{2}}(Gr_{x,\infty})^{1/4} \tag{36}$$

$$Nu_{x,w} = \frac{\psi(Pr)}{\sqrt{2}}(Gr_{x,w})^{1/4}. \tag{37}$$

Equations (36) and (37) refer to the classical solution with Boussinesq's approximation. This means that, in considering the variable fluid properties, the classical Boussinesq approximation is only suitable to the monoatomic gases when $T_w/T_\infty \to 1$, because the n_{c_p} of these gases tends to zero. For the biatomic gases, air and water vapour, the classical Boussinesq approximation could be approximately suitable when $T_w/T_\infty \to 1$, because n_{c_p} of these gases is generally 0.1 only. But for the polyatomic gases, because the variation of c_p with temperature is very obvious, the classical Boussinesq approximation is not suitable when $T_w/T_\infty \to 1$.

6. CONCLUSION

The method proposed in this paper, for analysing the laminar free convection of polyatomic gases along a vertical isothermal flat plate can be taken as a general one for all gases, and it could yield reliable results.

For the monoatomic, biatomic gases, air and water vapour, n_{c_p} is generally below 0.1, especially for monoatomic gases it actually tends to zero, n_{c_p} could be taken as zero when the variable fluid properties are considered.

In considering the variable fluid properties, as $T_w/T_\infty \to 1$, the classical Boussinesq approximation holds true for monoatomic gases, and nearly true for the biatomic gases, air and water vapour, but the classical Boussinesq approximation does not hold true for polyatomic gases in general.

The analysis, presented here, extends the one we reported previously [1].

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EFFET DES PROPRIETES THERMOPHYSIQUES VARIABLES SUR LA CONVECTION THERMIQUE LAMINAIRE DES GAZ POLYATOMIQUES

Résumé—On considère la convection naturelle de gaz polyatomiques dont la conductivité thermique, la viscosité et la capacité thermique varient avec la température absolue selon une loi puissance, la masse volumique étant inversement proportionnelle à la température absolue à pression constante, et le nombre de Prandtl étant constant. L'équation d'énergie est reconsidérée pour tenir compte de la variation de la capacité thermique avec la température et les équations de la convection naturelle laminaire sont traitées sous la forme d'équations différentielles sans dimension après transformation affine. On donne et discute les résultats numériques obtenus.

EINFLUSS VARIABLER THERMOPHYSIKALISCHER EIGENSCHAFTEN AUF DIE LAMINARE FREIE KONVEKTION IN EINEM POLYATOMAREN GAS

Zusammenfassung—Die vorliegende Arbeit behandelt die freie Konvektion in einem polyatomaren Gas, dessen Wärmeleitfähigkeit, Viskosität und spezifische Wärmekapazität gemäß einem einfachen Potenzansatz mit der absoluten Temperatur variiert. Die Dichte verhält sich bei konstantem Druck umgekehrt proportional zur absoluten Temperatur, während die Prandtl-Zahl als konstant angenommen wird. Die Energiegleichung wird so formuliert, daß die spezifische Wärmekapazität temperaturabhängig ist. Die partiellen Differentialgleichungen zur Beschreibung der laminaren freien Konvektion in einem polyatomaren Gas werden mit Hilfe einer Ähnlichkeitstransformation in die Form dimensionsloser gewöhnlicher Gleichungen gebracht. Diese werden numerisch gelöst. Die Ergebnisse werden diskutiert.

ВЛИЯНИЕ ИЗМЕНЕНИЯ ТЕПЛОФИЗИЧЕСКИХ СВОЙСТВ НА ЛАМИНАРНУЮ СВОБОДНУЮ КОНВЕКЦИЮ МНОГОАТОМНОГО ГАЗА

Аннотация—Свободная конвекция многоатомного газа исследуется в предположении, что теплопроводность, вязкость и удельная теплоемкость зависят от абсолютной температуры по простому степенному закону, плотность изменяется обратно пропорционально абсолютной температуре при постоянном давлении, а число Прандтля считается постоянным. Уравнение энергии преобразуется таким образом, чтобы учесть изменение удельной теплоемкости в зависимости от температуры, а определяющие уравнения в частных производных для ламинарной свободной конвекции многоатомных газов приводятся к безразмерным обыкновенным дифференциальным уравнениям с помощью преобразования подобия. Представлены и подробно обсуждаются результаты численных расчетов.