Rarefied Hypersonic and Micro/ Nanoscale Gas Flows and Heat Transfer

R. S. Myong, Ph.D.

Research goal

Pushing the limit of conventional gas dynamics (Navier-Stokes theory) based on new constitutive relations

Nonlinear Coupled Constitutive Relations (NCCR) and Langmuir slip models

- A unified framework for rarefied and micro/nanoscale gases
- Validated for various benchmark problems

Developing an efficient computational model for rarefied and micro/nanoscale gases

Combination of conservation laws and NCCR

- Aiming at replacing computationally inefficient DSMC in transition regimes
- Low computational cost comparable with NS codes
- Successfully applied to two-dimensional hypersonic flow

Applications of new models to hypersonic vehicles and micro/nano devices

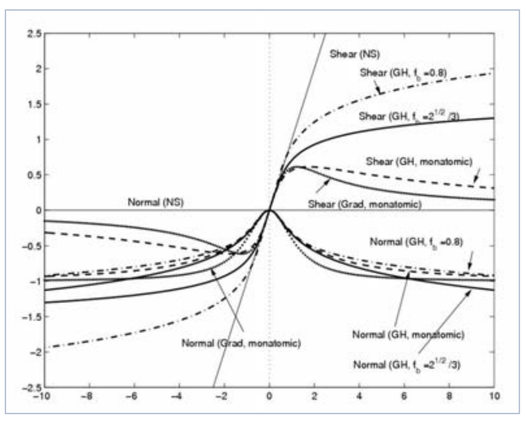
Prediction of aerothermodynamic coefficients (bridging formula)

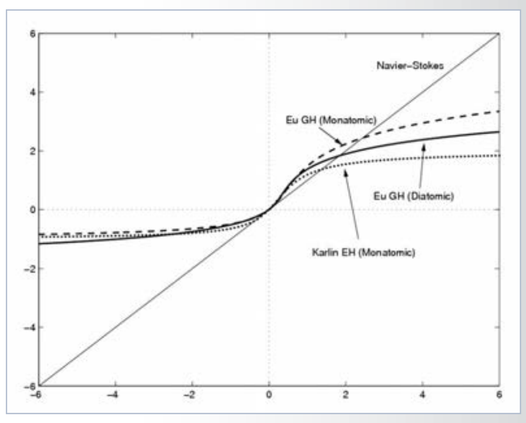
- Aerodynamic characteristics of reentry space vehicles
- New theory of force-driven microscale Poiseuille gas flows based on non-Fourier law

Milestones

New nonlinear coupled constitutive relations (NCCR)

Stress





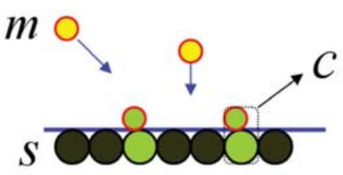
Thermodynamic force

Velocity shear gas flow

Compression-expansion gas

New Langmuir slip model

$$K = \frac{C_c}{C_m C_s} = \frac{N\alpha}{[p/k_B T_w]N(1-\alpha)},$$



$$\boxed{\alpha = \frac{\beta p}{1+\beta p}} \quad \text{where} \quad \beta = \frac{K}{k_B T_w}.$$

$m + s \Rightarrow c$

The fraction of gas molecules at thermal equilibrium

Dissemination of research outcomes

Journal of Computational Physics (Elsevier; 2001,2004)
Physics of Fluids (AIP; 1999, 2004, 2005, 2009, 2010)
Journal of Fluid Mechanics (Cambridge; 2009)
International Journal of Heat and Mass Transfer (Elsevier; 2006)
Shock Waves (Springer; 2008 A, B)
Continuum Mechanics and Thermodynamics (Springer; 2009)

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Collaborators

Prof. B. C. Eu (McGill University, Canada)
Dr. J. H. Park (Oak Ridge National Lab, US)
Prof. J. M. Reese (University of Strathclyde, UK)
Drs. D. Emerson and R. Barber (Daresbury Lab, UK)
Dr. Z. M. Hu (Temasek Laboratories, National University of Singapore, Singapore)
Dr. S. P. Nagdewe (Research Center for Aircraft Parts Technology, Korea)

Aerospace Computational Modeling Laboratory http://acml.gnu.ac.kr
Gyeongsang National University
Department of Mechanical & Aerospace Engineering