Comparison between extended thermodynamic of rarefied monatomic and polyatomic gases

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Extended thermodynamics has been developed to describe the nonequilibrium phenomena beyond the assumption of local equilibrium [1,2]. The prototype of the ET theory was proposed for rarefied monatomic gases [1]. The balance equations of this theory have a single hierarchy structure, starting from the conservation laws of mass, momentum and energy, in which the flux in one equation becomes the density in the next equation. On the other hand, recently, the ET theory for rarefied polyatomic gases was proposed by taking into account the effect of the internal motions of molecules through the degrees of freedom of a molecule and the characteristic variables of polyatomic gases [2]. This theory is based on the balance equations which have a binary hierarchy structure; one hierarchy consists of the balance equations for mass density, momentum density and momentum flux, the other one consists of the balance equations for energy density and energy flux.

The aim of the present talk is to compare the ET theories for rarefied monatomic and polyatomic gases, and then to make clear the relationship between these two theories. The following three topics are presented.

(i) The theoretical difference between the ET theories for rarefied monatomic and polyatomic gases is discussed. Then the nonequilibrium variables which characterize the polyatomic gases, such as the dynamic pressure, are introduced.

(ii) The role of the characteristic variables of polyatomic gases is discussed in the study of the linear waves. In particular, it is shown that the effect of the dynamic pressure appears in the typical behavior of the sound attenuation which is observed in experiments for fluids in which the bulk viscosity is larger comparing to the shear viscosity and the heat conductivity, such as the hydrogen and carbon dioxide gases [3].

(iii) It is proved that the solutions of the ET theory for polyatomic gases coincide with those for monatomic gases in the singular limit, i.e., the limit that the internal degrees of freedom approach to 0 with an appropriate initial condition with monatomic gases [4,5]. In this proof, the method of molecular extended thermodynamics [1,2,6] is adopted.

[1] I. Müller, T. Ruggeri: Rational Extended Thermodynamics, Springer Tracts in Natural Philosophy **37** (II edition), Springer-Verlag, New York (1998)

[2] T. Ruggeri, M. Sugiyama: Rational Extended Thermodynamics beyond the Monatomic Gas, Springer, Cham, Heidelberg, New York, Dordrecht, London (2015).

[3] T. Arima, S. Taniguchi, T. Ruggeri, M. Sugiyama. Cont. Mech. Thermody., **25**, 727-737 (2013).

[4] T. Arima, T. Ruggeri, M. Sugiyama, S. Taniguchi, Ann. Phys. **372**, 83-109 (2016).

[5] T. Arima, S. Taniguchi, T. Ruggeri, M. Sugiyama, Lett. A. **377**, 2136–2140 (2013)

[6] T. Arima, A. Mentrelli, T. Ruggeri, Ann. Phys. **345**, 111–140 (2014).