Radiative Cooling and Collapse-Comparative study of a range of gases

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Introduction

- A recent paper showed the effects of radiative collapse on the Kr plasma focus computed from the Lee Model code [S Lee, S H Saw and Jalil Ali, J Fusion Energ (2013) 32: 42-49].

In this paper we carry out series of numerical experiments in NX2 on H_2, D_2, He, N_2, Ne, Ar, Kr and Xe in order to compare the effect of radiative cooling and collapse on plasma focus operation in these gases.

- The radiation-coupled dynamics of the code includes Bremsstrahlung, recombination radiation and line radiation and also the effects of compressibility due to thermodynamics quantified through the specific heat ratio SHR of the gas. The results may be expressed graphically as follows:

The results:

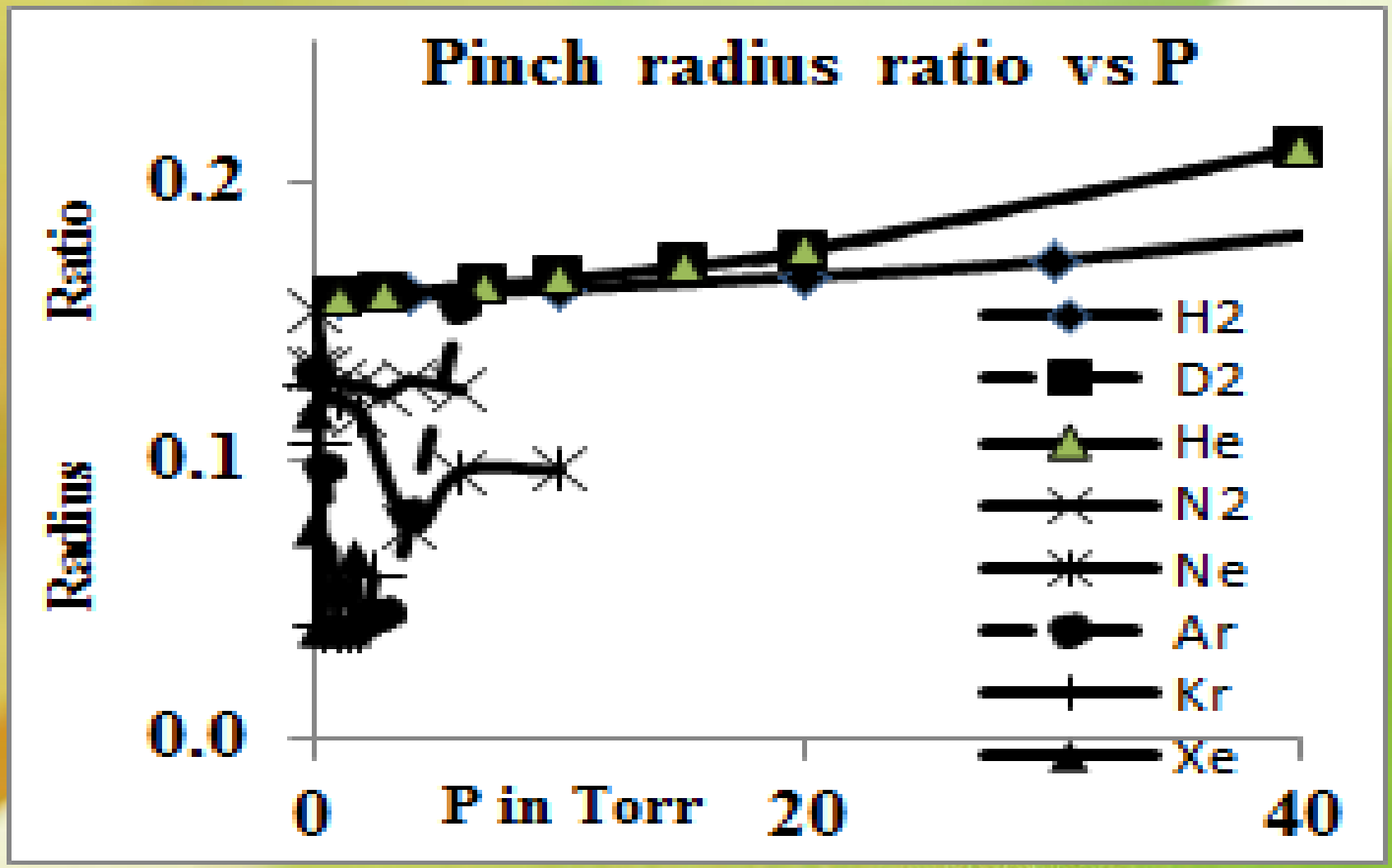
Pinch radius ratio vs P
Ratio
Radius
0.2
0.1
0.0
0
P in Torr
20
40
H2
D2
He
N2
Ne
Ar
Kr
Xe

Fig 1. Pinch Radius Ratios in various gases

- Figure 1 shows that the lightest gases H_2, D_2 and He have radius ratios (r_{min}/a where r_{min} is the minimum pinch radius reached during compression and 'a' is the anode radius) which rises from a value of 0.15 towards 0.2 as the operational pressure rises.

Fig 2. Magnifying the low pressure range to show the radius ratios of the heavier gases

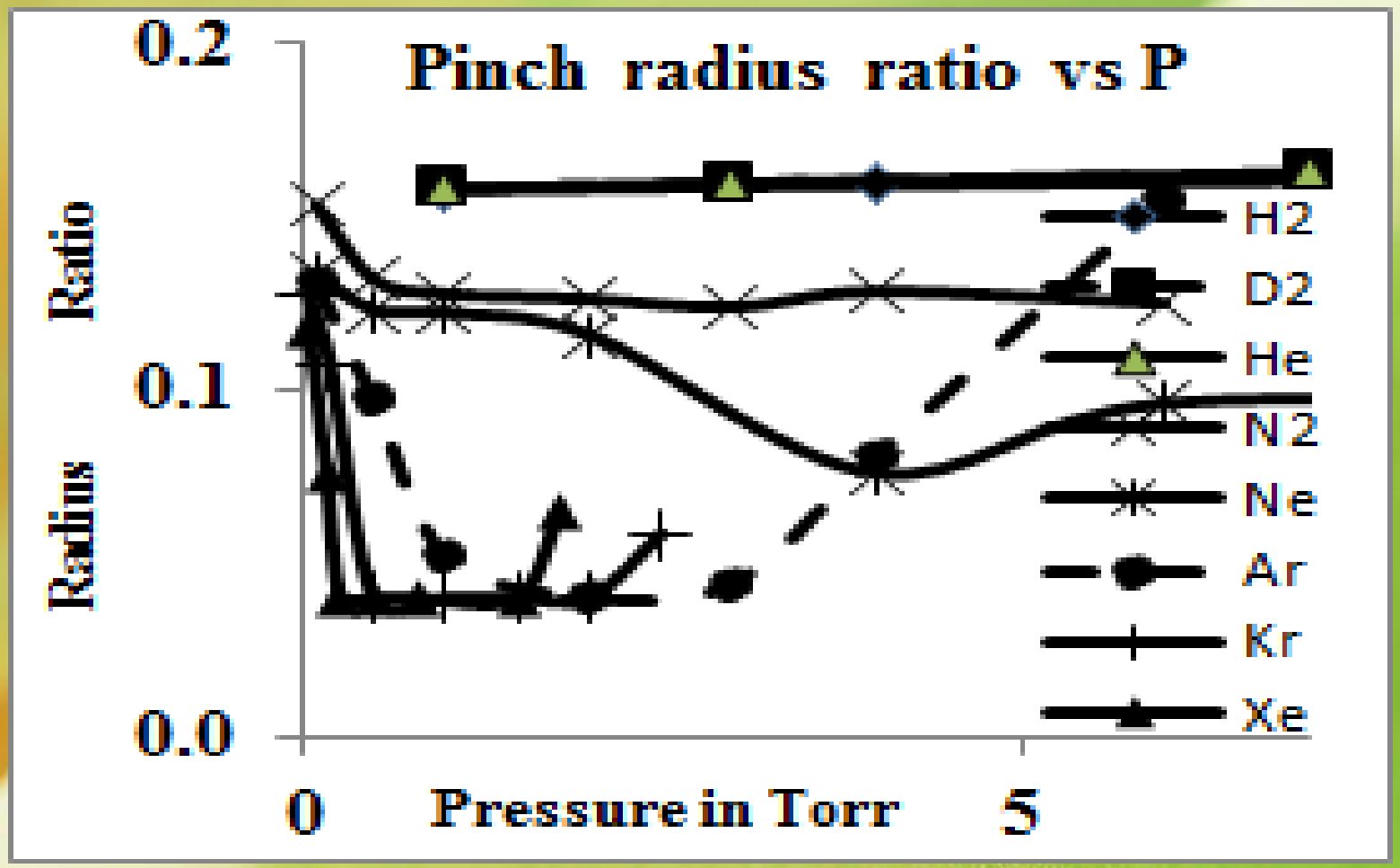

Fig 2. Magnifying the low pressure range to show the radius ratios of the heavier gases

- N_2 has a drop in radius ratio from 0.15 at 0.1 Torr to 0.13 at 1 Torr and stay at about that value up to its highest operational pressure of 6 Torr.
- Detailed study of the computed properties shows that this drop in radius ratio is due to SHR effects.
- Neon shows the same SHR effects until 2 Torr when a further dip to 0.07 occurs due to radiative cooling.

Radiative Collapse Gases

- For Ar there is a small range of low pressures down to 0.2 Torr when the SHR is apparent before radiative collapse takes over to plunge the radius ratio to 0.04 between 2 to 3 Torr.
- For Kr and Xe the radiative collapse is completely dominant over nearly the whole range of operation.

Radiative Powers

- An analysis of the radiation shows that in the range of operations of the plasma focus the radiative cooling and collapse is completely dominated by line radiation.

- The line radiation has the form

radiative power $dQ_L/dt \sim Z_{eff}^2 Z_n^4 r_p^{-2}$

where Q_L is the energy emitted from the pinch with consideration of plasma self-absorption,

Z_n is the atomic number,

Z_{eff} is the effective charge number of the plasma due to ionization and r_p is the plasma focus pinch radius..

Ratio of Radiative Power

- For operation of NX2, Ne is the lightest gas to start showing enhanced compression due to radiative cooling. Taking the radiative power of Ne as 1, the radiative powers of Ar, Kr and Xe are evaluated to be respectively 61, 2600 and 7500.

Conclusions: (Radiative Cooling and Collapse-Comparative study of a range of gases)

- Our Model code computes the radius ratios of various gases as a function of pressures
- The lightest gases up to He shows simple pinch compression characteristics
- N2 (nitrogen) shows clear signs of SHR enhanced compression
- Neon shows SHR-enhanced as well as radiatively enhanced compressions
- Ar, Kr and Xe experience pinch compressions completely dominated by radiation