Nuclear moment of inertia in super-normal phase transition region[†]

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The purpose of this paper is to derive the analytic expression for the angular momentum (I) dependence of the moment of inertia (MoI) from the microscopic many-body theory both for even-even and odd-mass nuclei. The I-dependence of MoI has been proved to be essential in simulating triaxial, strongly deformed (TSD) bands in a series of papers.[1–4)]

We adapt the approximation developed for the gap (Δ) dependence of the ratio of MoI (J) to the rigid-body value (J^{rig}).[5,6)] It assumes that only large matrix elements of single-particle angular momentum of $(j_x)_{\alpha\beta}$ contribute to J with a common excitation energy of $\delta(=\varepsilon_\beta - \varepsilon_\alpha)$, where ε_α denotes the single-particle energy of the level α. We apply this approximation to the gap equation including the Coriolis anti-pairing (CAP) effect[7)] through the second-order perturbation to the cranking term.[8,9)]

When Δ is larger than half of the single-particle level distance d, we can apply a definite integral for the gap equation with the CAP effect. When Δ is smaller than half of d, we propose the finite sum method with the picket-fence approximation for the level distribution. In this case, it is proved that Δ never tends to zero, and there is no sharp phase transition from the superconducting state to the normal state. Neglecting the higher order in $2\Delta/\delta$ for the case $\Delta < d/2$ (finite sum method), we express MoI as an analytic function of I.

In Fig. 1, we compare the approximate solution between even-even and odd-mass nuclei as functions of I measured from the band-head angular momentum I_0. Usually, $I_0 = 0$ for even-even nucleus, while $I_0 \neq 0$ for odd-mass nucleus, for example, $I_0 = 13/2$ for the TSD yrast band in ^{163}Lu.[10)] We choose the single-particle energy for a valence nucleon as $\varepsilon_\ell = 0.6$ MeV above the Fermi surface, and the initial pairing gap at $I=I_0$ for odd mass as 0.6 MeV, smaller than 0.8 MeV for even-even nucleus (blocking effect). The blocking effect reduces the starting value of Δ and increases that of the MoI. In odd-mass case, there is a term that correlates the single-particle state of ℓ with α through $(j_x)^2_{\alpha\ell}$. The matrix element of $(j_x)^2_{\alpha\ell}$ is chosen to be 12 for $\varepsilon_\alpha > \varepsilon_\ell$ and 10 for $\varepsilon_\alpha < \varepsilon_\ell$. The other parameters are the same as those for the even-even case. We have started both approximate solutions with $\Delta = 0.15$ MeV corresponding to $I-I_0 \sim 15$, while $d = 0.4$ MeV.

As is seen in Fig. 1, the main difference between even-even (dashed line) and odd-mass (solid line) nuclei is from the blocking effect. Then, both curves increase gradually, and approach the value 1. The MoI of odd-mass case is chosen to be slightly larger than that of the even-even case. The curves become convex upward before they reach to rigid-body values. This upward convexity is also necessary for explaining the energy sequence of TSD bands.[4)] For the case of $\Delta \geq d/2$ (definite integral), J goes to J^{rig} around $I-I_0 \sim 17$ or 18 (sharp phase transition). Even in this case, odd-mass nuclei show an upward convexity before the phase transition at $I=17 \sim 18$. Because of larger I_0, the slow phase transition occurs at larger I for odd-mass nuclei than for even-even nuclei.

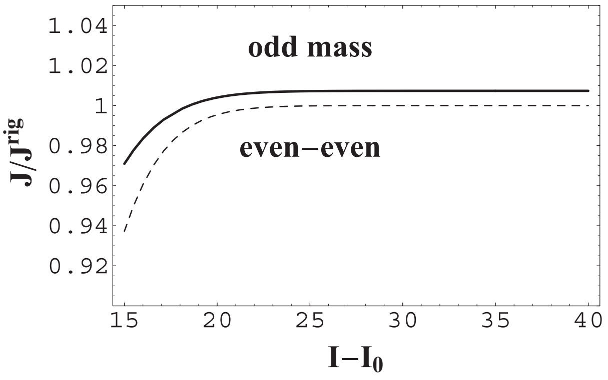

Fig. 1. Comparison of the ratio J/J^{rig} in the approximate sum method as functions of I-I_0 for even-even (dashed line) and odd-mass (solid line) nuclei.

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