

Relation of shell form to rocking motion in planispiral cephalopods

*Takao Ubukata¹

1. Division of Geology & Mineralogy, Department of Earth & Planetary Sciences, Kyoto University

In Recent *Nautilus*, thrust force produced by the hyponomic jet acts to rotate the shell resulting in a rocking motion during swimming. This instability is a potential problem for any other ectoconchleate cephalopods with planispiral conchs when they swim. A smaller distance between the center of gravity and center of buoyancy tends to cause a large rotation of the shell. For this reason, it has long been imagined that ammonoids with long body chambers are less stable than *Nautilus* during swimming. In contrast, it has also been considered that a long body chamber places the aperture higher and positions the hyponome at the same level of the center of gravity so that the hyponomic jet can act directly through the center of gravity. Previous discussions on static stability of ectoconchleate cephalopods largely focused on indirect assessment based on the aperture orientation and the position of the center of gravity and center of buoyancy. The present study assessed the angle of rocking motion for various shell forms of planispiral cephalopods to generalize the relationship between conch geometry and static stability. The angle of rocking motion was computed for theoretical morphologic models based on force and moment balance presuming a neutrally buoyant condition. The thrust force of hyponomic jet was assumed to be expelled from the ventral edge of the aperture and to generate a moment which is opposed by the restorative moment produced by inclination of segment between the center of gravity and center of buoyancy. Form drag and shear stress acting on the shell moving with respect to surrounding water were ignored in calculating the opposing moment. The inclination angle of the segment between the center of gravity and center of buoyancy was regarded as the angle of rocking motion and was computed for each theoretical model with given values of whorl expansion rate, relative umbilical width, and relative whorl breadth. The result revealed following: (1) The angle of rocking motion fluctuates with changes in the whorl expansion rate (W) if the value of W is small enough so that the body chamber is more than one whorl in length. In this condition, the rocking angle varies sensitively to the change in W . (2) The rocking angle is large when the shell is slender. (3) The rocking angle does not highly depend on the relative umbilical width. These results indicate that the long body chamber resulting from a small W does not always allow the animal stable swimming and a slight intraspecific or ontogenetic variation in W may cause drastic change in static stability in such form. The result suggests that such static instability limits swimming ability in some ammonoids with tightly coiled conchs.

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