Contribution ID: **433** Type: **Oral**

Shape sequence of rope coiling on a rotating plane

Tuesday, 22 May 2018 13:30 (15 minutes)

Rope fed uniformly from the height exhibits a perfectly circular coiling on a static plane. Introducing the rotation to the plane breaks the rotational symmetry of circle which gives rise to a variety of the more ordered patterns. For sufficiently fast feeding velocity v the coiling shape laying on a rotating plane is a hypotrochoid, namely a closed curve with exterior loops, when plane rotates slowly with low frequency f_0. As f_0 increases, the number of exterior loops decreases and the shape eventually turns to an epitrochoid, namely a closed curve with interior loops. The hypotrochoid-to-epitrochoid transition associates with a change in the sign of angular momentum. As f_0 increases further, the number of interior loops gradually decreases to zero and the shape thus turns to a circle. Interestingly the circle which is the shape for static plane is restored at fast plane frequency f_0, rather than at slow plane frequency f_0 as our intuition would suggest. To elucidate the underlying principles, all the experimentally observed shapes, i.e. hypotrochoid, epitrochoid, and circle, are unified by a geometrical description. The key parameter which controls the shape is the ratio of the circumference velocity of plane relative to the feeding velocity, namely $2\pi f_0 R/v$ where R denotes the radius of the shape. The feeding velocity-plane frequency phase diagram is presented.

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Session Classification: A17: Statistical and Theoretical Physics

Track Classification: Statistical and Theoretical Physics