Stability features of the laminar wake behind a spinning slender blunt-based body

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The intense work devoted to wakes behind bluff bodies has provided with a deep understanding of their stability properties, featuring many of these flows similar bifurcation patterns. Thus, in line with the sphere, the wake behind a slender blunt-based body remains axisymmetric until $Re = Re_{cs}$, where it undergoes a first transition towards a steady state regime, characterized by two counterrotating planar-symmetric streamwise vortices. Furthermore, as Re is increased over a second critical value, Re_{co}, a Hopf bifurcation takes place, emerging an oscillatory regime of vortex shedding that retains the planar symmetry. The control of these two regimes arises as a problem of importance and, considering the large sensitivity that axisymmetric bodies exhibit in the recirculation bubble, investigating the effect of rotation on the flow transitions can be an appealing approach. On the other hand, despite of the importance of streamwise rotating bodies in aerodynamics or turbomachinery, or recently in microscale systems (e.g. microrobots and micro-combustors), there are very few works addressing the transitions in the wake for laminar flows.

Following these concerns, we have performed numerical simulations and global stability analysis for the laminar flow past a rotating slender blunt-based body, with moderate angular rotation velocities, and covering a wide range of Reynolds number. Our results reveal that, when spin is applied, the aforementioned unstable regimes for the natural wake are largely modified, leading to more complex topologies. In particular, the steady state mode features now streamwise vortices co-rotating with the body, at a different velocity, without change in the shape nor intensity, describing a *frozen* wake in a reference system rotating with the structures. Besides, the vortex shedding regime adopts a rotating unsteady spiral configuration that, as the rotation parameter grows, arrange into a new co-rotating *spiral frozen* wake, which is the only unstable regime found for moderate rotation parameters in the range of Re investigated. This spiral frozen regime dominance at moderate spin is accompanied by the stabilization of the first *frozen* regime. Hence, for some $Re > Re_{cs}$ it is possible to retrieve axisymmetry when the spin parameter increases, acting rotation as a control mechanism. Moreover, at higher rotation velocities, a third co-rotating *frozen* regime emerges for low Reynolds number, breaking again the axisymmetry.

According to the global stability analysis of the axisymmetric base flow, the different bifurcations from the axisymmetric state towards the unstable nonlinear regimes described, can be explained in terms of the destabilization of three distinguished global linear modes with azimuthal wavenumber $m = -1$. These results resemble other reported for swirling flows, e.g. vortex breakdown, where co-rotating structures are triggered by destabilization of helical unstable modes. Finally, we point out that, since the axisymmetric base flow is SO(2)-symmetric, the weakly non-linear regimes that emerge close to criticality must necessarily take the form of rotating-wave states (i.e. *frozen* wakes).

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