Topology of helical fluid flow

Considering a coordinate-free formulation of helical symmetry rather than more traditional definitions based on coordinates, we discuss basic properties of helical vector fields and compare results from the literature obtained with other approaches. In particular, we discuss the role of the stream function for the topology of the streamline pattern in incompressible flows. On this basis, we perform a comprehensive study of the topology of the flow field generated by a helical vortex filament in an ideal fluid. The classical expression for the stream function obtained by Hardin (Hardin, J. C. 1982 Phys. Fluids 25, 1949–1952) contains an infinite sum of modified Bessel functions. Using the approach by Okulov (Okulov, V. L. 1995 Russ. J. Eng. Thermophys. 5, 63–75) we obtain a closed-form approximation which is considerably easier to analyse. Critical points of the stream function can be found from the zeroes of a single real function of one variable, and we show that three different flow topologies can occur, depending on a single dimensionless parameter. By including the self-induced velocity on the vortex filament by a localised induction approximation, the stream function is slightly modified and an extra parameter is introduced. In this setting two new flow topologies arise, but not more than two critical points occur for any combination of parameters.

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