Asymptotic Suction Boundary Layer - Nonlinear Eigenfunctions, Nonlinear Stability and Coherent Structures

An essential finding and key object of the present research project is the fact that for a number of shear flows, in particular for the linear shear flow, the logarithmic and the exponential velocity profiles, a nonlinear eigenvalue problem (NEVP) can be formulated, which both represents an inherently nonlinear stability problem and forms the basis for nonlinear coherent structures. The above-mentioned scaling laws also apply in marginally modified form to the present flow problem of an asymptotic suction boundary layer (ASBL). The NEVP is an essential extension of the proposal of the first period, in which for the flow profiles mentioned above it was found, that for the linear stability problem additional symmetries exist, which go beyond those implicitly used for the derivation of the Orr-Sommerfeld equation. These new symmetries gave rise to alternative modes, e.g. with double exponential temporal growth and decay rates. The new nonlinear approach thus allows a seamless transition from linear to fully nonlinear stability analysis. Interestingly, in the NEVP the scaling parameters of the above-mentioned turbulence laws, e.g. κ for the logarithmic law, which have their origin in the group parameters of the symmetry-invariant solutions, appear as eigenvalues of the NEVP. With this, the question of stability and large-scale turbulent structures may be put under a common umbrella. This is particularly interesting because the structure of the NEVP allows a variational formulation, e.g. following the Rayleigh-Ritz variational method, so that the eigenvalues and eigenfunctions satisfy an extremalizing principle. In contrast to classical eigenvalue problems, the NEVP does not allow for a superposition principle, so it should rather be understood as a branching problem depending on the eigenvalue, since only one eigenvalue can be active at a time. The linear shear flow in an infinite domain serves as a benchmark for method development to finally analyze the logarithmic and exponential laws. A viscous extension of the NEVP is intended by means of singular approximative symmetry group methods. Using different analytical methods and numerical schemes, especially discontinuous Galerkin methods, the solution behaviour of the NEVP will be investigated. The results will be compared with the DNS data of the ASBL simulations performed in the first period and with linear stability theory. For the extraction of the large turbulent structures in the DNS data, various techniques of other groups in the priority program will be employed.