The sonic singularity of the parabolized Navier-Stokes equations

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The parabolized Navier-Stokes equations are often used for the computation of viscous super-sonic high-Reynolds number flows. Although separation in the main flow direction must be excluded, separation and reattachment of the cross-flow can accurately be predicted by integrating the simplified conservation equations with a marching technique and by extrapolating the flow variables into the subsonic part of the flow. Agreement of predicted wall pressures with measured data is good, but predicted wall heat transfer and also wall shear stress often deviate from measurements. One possible reason for these discrepancies is the singular behavior of the parabolized Navier-Stokes equations, when the streamwise velocity component becomes sonic. It is known from the slender channel approximation of the Navier-Stokes equations for viscous supersonic nozzle flow, that the sonic singularity can cause substantial errors in the wall shear, and the same arguments seem to apply here. However, these difficulties can be avoided if Prandtls boundary-layer theory is used for the subsonic part of the flow: Since the sonic surface is located deep inside the boundary layer, close to the wall, the boundary-layer approximation is valid, and the singularity can be excluded. Thereby the accuracy of the prediction can be improved, as the solution is not effected by the singular behavior of the simplified conservation equations.