Description of boundary layer transition from laminar to turbulent state using directed percolation

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Describing and modeling the transition from a laminar to a turbulent flow is still one of the most challenging problems in fluid dynamics. In recent years many studies show a good agreement between characteristics of transition and directed percolation (DP), like already proposed by Pomeau[1]. Many of those studies focus on canonical, wall-bound flows with simple geometries[2,3,4]. But also more complex application-oriented cases show agreement with the universality classes of DP when describing the behavior of the system[5,6]. Mentioned studies and also recent publications[7,8] indicate the topicality of the application of this new approach in fluid dynamics.
In this present study differential image thermography (DIT) measurements are used to investigate the boundary layer transition of a heated airfoil. The benefit of using DIT is the applicability to complex curved surfaces. Therefore, the evolution of the boundary layer can be captured and the model of DP can be applied to measured data. Additional, a wide range of parameters has been investigated in the study. Both the inflow velocity u_∞ and the angle of attack α were varied to test the model for different conditions. The results indicate the applicability of DP to locate and describe the onset of transition for the boundary layer of an airfoil with high accuracy.
A thermogram is shown in Fig. 1(a) with the resulting temperature gradient and the determined transition point. Fig. 1(b) shows the resulting turbulent fraction ρ including a fit for (1+1)D directed percolation.

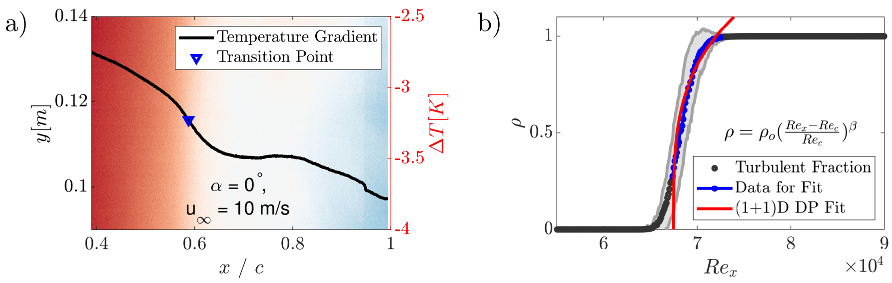

Figure 1: (a) Thermogramm of airfoil suction side with temperature gradient (black) and transition point (blue). (b) Turbulent fraction ρ along the chord based Reynolds Number Re_x with (1+1)D directed percolation fit.

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