Experimental Investigation of Turbulent Flow Separation on the BeVERLI Hill

Nicole-Marie Sa'adeh[1], Daniel MacGregor[1] & Philippe Lavoie[1]
1 Institute for Aerospace Studies, University of Toronto, Toronto, Ontario, CANADA

The BeVERLI hill is a three-dimensional bump designed by NASA and Virginia Tech to experimentally study turbulent flow separation. Bump models such as the BeVERLI hill are designed to subject an incoming flow to strong favourable (FPG) and adverse pressure gradients (APG) due to the varying surface curvature of the bump geometry, thus facilitating a detailed study of the boundary layer dynamics and separation phenomena. As part of NATO's AVT-413 panel, *Physics and Modeling of Separated Flows Around Smoothly-Curved Bodies*, detailed data from experimental campaigns have been collected at the University of Toronto Institute for Aerospace Studies (UTIAS) on the BeVERLI hill, with the aim of better understanding the underlying physics of flow separation due to surface curvature.

The BeVERLI hill is described by a fifth-degree polynomial mirrored along the centerline with a flat top. It features an adverse pressure gradient at the upstream base of the hill, followed by a favourable pressure gradient at about half way on the upstream slope of the hill, an APG to FPG switch at the flat top where the switch occurs right at the bump apex, and finally an APG downstream. Experiments were conducted in the subsonic recirculating wind tunnel at UTIAS at the 45° case, which is when the centreline polynomial is at a 45° angle to the incoming flow. The Reynolds number is based on the height of the bump, h, which is 0.12 m, and the main focus was on $Re_h =$ 38k, 123k, and 208k. Additionally, the hill features 135 pressure taps.

The data collected includes surface pressure measurements, flowfield measurements using planar Particle Image Velocimetry (PIV), and surface oil flow visualization. Surface pressure contours on the hill show the static pressure coefficient, C_p, as a function of normalized streamwise and spanwise position, x/h and z/h respectively. The pressure distribution along the centreline (i.e. at $z/h = 0$) reveals an early flow separation at the lowest Reynolds number tested. This early flow separation is indicated by the shallow slope of the APG downstream of the bump apex seen in the centreline plot, implying that the flow had not recovered, but separated instead. This phenomenon is also seen in the centrespan C_p plot, with the indication being an almost constant C_p - much higher in value than that of the higher Reynolds numbers, pointing to a separation bubble much further upstream at this low Re_h.

Additionally, data extracted from the PIV measurements along the XY plane depict the developing boundary layer at the three Reynolds numbers mentioned above. The results from investigating the boundary layer development further reiterates the Reynolds number trend seen with flow separation. Moreover, streamline mapping using surface oil flow visualization paired with an Open-Source Python algorithm from TU Berlin aids in visualizing the flowfield and separation region on the hill.

Email address for correspondence: *nicole.saadeh@mail.utoronto.ca*