On the flow resistance of wide surface structures

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It has been shown that riblet-mounted surfaces can reduce the skin-friction drag by up to 10% compared to flat surfaces in turbulent channel flows [3]. In the laminar regime, however, the use of these surface geometries was found to result in drag increase [2]. Using a variational principle for the surface shape, Pironneau et al. [4] were able to show analytically that in the laminar case benefits can only be expected if the surface structures are wide enough compared to the channel height, in particular if the ratio obeys the condition $l/L > \pi/z$ where $z \approx 1.2$ is the root of $1 - x \tanh x$ ($2l$: width of the structure, $2L$: mean channel height). In the present investigation the curved optimum surface shape found numerically by Pironneau et al. is analysed further. Using an analogy between structural mechanics and fluid mechanics, namely the analogy between torsion of beams and fully developed laminar flow in ducts (the governing equation in both cases is Poissons equation), the pressure drop, and thus the skin-friction drag, arising from various curved structures can be calculated using Saint Venants principle [1]. In this respect the analysis concentrates on surface modifications described by a trigonometric function of the form $x_2 = \pm((a/2)\cos(\pi x_3/l) + 2b)$ with $b + a/2 = L$. Based on this approach the impact on flow resistance for the variation of all parameters determining the trigonometric structure is taken into account. Drag is found to be reduced up to about 50% compared to the flow through a rectangular channel of the same cross section and the same width (here: $2l$) for a certain range of parameters. In addition, numerical simulations of the flow in the structured channels are performed. Currently, these simulations are extended to higher Reynolds numbers in order to also study the drag reduction potential of these wide surface structures in turbulent flows.

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