Assessment of Flow Control Techniques in Terms of Time and Energy Savings

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The performance of drag reducing flow control techniques for internal flows is customarily evaluated by either measuring the flow rate achieved with a fixed pressure drop or determining the pressure drop needed to drive the flow at a fixed flow rate. The obtained results are typically presented in a plot of skin friction drag (i.e. pressure drop) versus bulk Reynolds number (i.e. flow rate) where either the reduction of skin friction drag at fixed Reynolds number or the increase of Reynolds number at a fixed skin friction drag represent successful control. In this conventional $c_f - Re-$plot the two key aspects of practical fluid transport systems, namely the time required to transport a given amount of fluid over a certain distance and the energy required to realize this transport, cannot be viewed independently. This mainly stems from the fact that the energy consumption is directly related to the product of flow rate and pressure drop. Based on the idea to put potential energy and time savings in the focus of flow control evaluation we derive two dimensionless parameters which quantify the energy consumption and the transportation time for flows through an arbitrary duct independently. These parameters span a novel evaluation plane that allows reevaluating the performance of passive and active drag reduction techniques in one framework also including the energy expenditure to run active control. This novel evaluation plane allows including application-dependent cost functions such that the optimal control strategy for a given application can be determined.