Investigation of a turbulent channel flow in presence of a non-uniform magnetic field: MHD control.

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Abstract: Turbulence control is a key issue in many industries, such as aviation and metallurgy. In the latter sector, uniform magnetic fields generated by electromagnets are regularly used. However, these systems are massive and energy consuming. In other more exotic applications such as marine propulsion, turbulence control can also be attempted by using magnets and injecting an electric current to take advantage of the Laplace force. But again, the approach is energy intensive and likely to result in electrolysis if the conductive fluid medium is salt water.
The thesis considered here proposes an alternative approach using the non-uniform magnetic field delivered by an array of permanent magnets distributed along a channel wall. The behaviour of a turbulent flow modified in this way is studied using Direct Numerical Simulations (DNS). The magnets allow to act on the flow without external addition of energy while being more manipulable and less cumbersome than an electromagnet: the electric currents and Laplace forces are induced by weak coupling between the magnetic field and the flow.

It is shown that the magnetic field must be imposed at least over the thickness of the inner layer (thus including the logarithmic layer) in order to significantly influence the turbulent flow in a channel. Two elementary configurations of permanent magnets are therefore proposed and numerically solved, which allow to preferentially impose a streamwise or spanwise magnetic field in the near-wall region.

The spanwise magnetic field configuration is the most effective in reducing turbulent activity in the flow, while the configuration generating mainly a streamwise magnetic field significantly increases the agitation and thus the mixing. Several variants of the spanwise magnetic field configuration are then studied. It is shown that the more homogeneously the magnetic field is distributed in the inner layer of turbulence, the more effective it will be in reducing turbulent activity. The distance between the selected magnets and their respective magnetic intensities are also determining parameters that must be optimised.