Dolphin-Inspired Drag Reduction for Ships

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ABSTRACT

Dolphins are able to sustain an underwater speed of about 9 m/s across long distances\textsuperscript{1}. This fascinating endurance has led to the hypothesis that the thick, pliable dolphin skin ('blubber') keeps a large portion of the boundary layer laminar (delay of transition to turbulence), thus acting as a drag-reducing passive flow-control device. In the project FLIPPER\textsuperscript{2}, we investigate the possibility of transferring the dolphin's control strategy to the flow around the bow of a small ship (Fig. 1a). To this end, blubber-like polymeric coatings are currently being developed and will soon be tested in a water tunnel, using a 1:4.5 scale model of the ship ($Re\sim$36 million). In preparation of these tests, we have carried out RANS-based flow simulations around the ship model coupled to boundary-layer computations, where the laminar boundary layer over the ship bow has been modelled by a Falkner-Skan profile. Spatial Orr-Sommerfeld stability calculations and $e^N$ transition predictions have been conducted for this profile in order to estimate the transition location on the bow and the spectrum of Tollmien-Schlichting (TS) wave frequencies involved (Fig. 1b). The same flow conditions have also been studied in three-dimensional Lattice-Boltzmann simulations so as to capture the nonlinear phase of the TS waves and their breakdown to turbulence.

The Orr-Sommerfeld solver\textsuperscript{3} was recently augmented by a dynamic model for compliant surfaces\textsuperscript{4}. Preliminary calculations reveal that a substantial stabilisation of the TS waves can be achieved when using compliant coatings with low $E$ modulus (Fig. 1c); on the other hand, wall compliance may foster surface instabilities ('travelling-wave flutter') at the risk of premature transition\textsuperscript{1}. Estimates for the drag-reducing potential of the investigated coating materials will be included in the conference talk.

Keywords: Drag reduction, compliant-coating flow control, boundary-layer transition delay

References