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Influence of repetitive laser pulse energy depositions on supersonic flow over a sphere, cone and oblate spheroid

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Abstracts

In this work, numerical simulation of active flow control of high speed flows by means of unsteady laser energy deposition was conducted. Supersonic flow over a sphere, cone and oblate spheroid was studied. The effect of single and multiple laser pulses on reduction of the drag force over these aerodynamic nose shapes were studied and compared. In addition, the effect of Mach number, location of energy deposition, number of laser pulses and the frequency of energy deposition were studied. A solver was developed for OpenFOAM to simulate the compressible flow at high Mach numbers. The shock capturing property of the solver was improved using AUSM+-up to calculate the pressure and velocity fluxes at the cell faces. For the validation purpose, simulation of the unsteady laser energy deposition in supersonic flow over a sphere was compared with experimental data. The results of single laser pulse deposition indicated that the interaction of the blast wave and bow shock leads to increase in the drag force. However, when the total laser energy was divided to smaller energy pulses and was applied at high frequency, the maximum drag force was decreased significantly and duration of drag reduction was increased. In addition, it was observed that by increasing the number of laser pulses and the distance between the energy deposition location and body, the duration of drag reduction was increased. In the end, energy saving efficiency for all the simulated cases was calculated. The energy saving efficiency was increased significantly by an increase in the free stream Mach number in spite of the decrease in the duration of drag reduction phase. For the conditions tested here, the maximum energy saving efficiency for supersonic flow over a cone was 65%, while it reached to as high as 750% and 460% for supersonic flow over a sphere and oblate spheroid.

Keywords: Laser deposition, Drag reduction, Flow control, Supersonic flow