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Numerical Investigation of Rod Vortex Generators on Hovering Helicopter Rotor Blade

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High thrust of the helicopter rotor in hover induces severe flow conditions at the rotor blade. Shock waves appear at the tips of blades, which usually lead to flow separation. In order to improve the rotor effectiveness it is necessary to implement some flow control device. In this paper application of a new Rod Vortex Generator (RVG) [1] is presented. Caradonna-Tung model helicopter rotor in hover [2] is studied.

The high-speed transonic conditions, which exist on this two bladed rotor cause a shock-wave induced flow separation. Rod vortex generators are able to delay flow separation due to the creation of the streamwise vortices. RVGs enforce an exchange of momentum in the direction normal to the wall. High momentum air is transferred to the low momentum region and therefore separation is reduced.

The authors are putting a big effort in the study of flow control strategies [3-5] which may be implemented in the next generation of aircrafts. Recently own invention of RGV is investigated. For this purpose, several rod vortex generators were placed in the suction side of the rotor blade in order to study their influence on flow separation.

The present investigation was carried out with the FLOWer solver from DLR. The code solves the Reynolds-averaged Navier-Stokes equations (RANS) and allows the use of the chimera overlapping technique. The mathematical model was validated by the comparison of numerical results with measurements of the clean rotor blade. The Caradonna-Tung experimental data is extensively used for validation of CFD codes for rotorcraft applications. The pressure distribution at r/R=0.96, the Mach contour map at the same cross-section (it is visible flow separation induced by shock wave) and the blade wake is shown in Figure 1.

RVGs dimensions were designed according to the boundary layer thickness of the clean flow case, while the number of rods in spanwise direction is set according to the length of separation bubble. Figure 2 shows how a single rod is able to create a streamwise vortex. There is a comparison of the separation bubble for the clean case and passive control (RVGs) case on the right side of the figure 2.

The application of vortex generators on the helicopter rotor blade in hover conditions confirms that it is possible to reattach the flow to the wall. The aerodynamic performance of a helicopter rotor may be improved: thrust is increased and/or torque is decreased.

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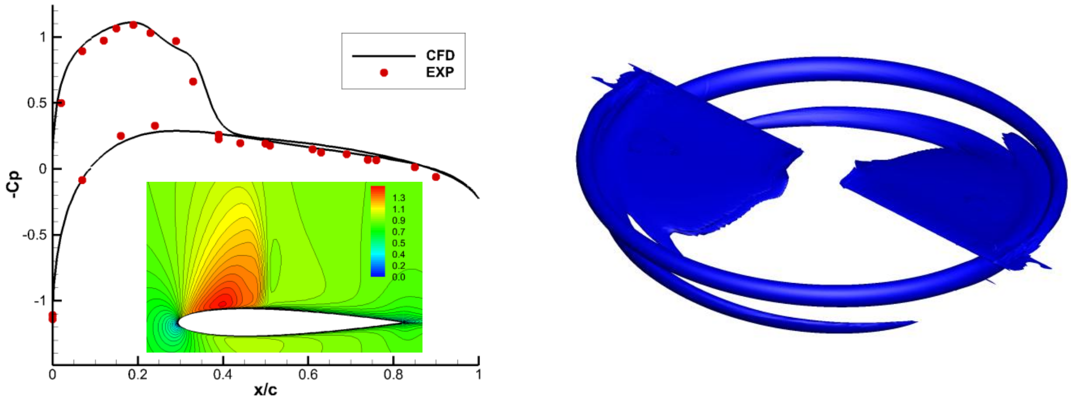

Figure 1. Caradonna-Tung rotor in hover. Clean case, M_{TIP}=0.877, $\Theta_{collective}$=8, Re=$3.93\cdot10^6$

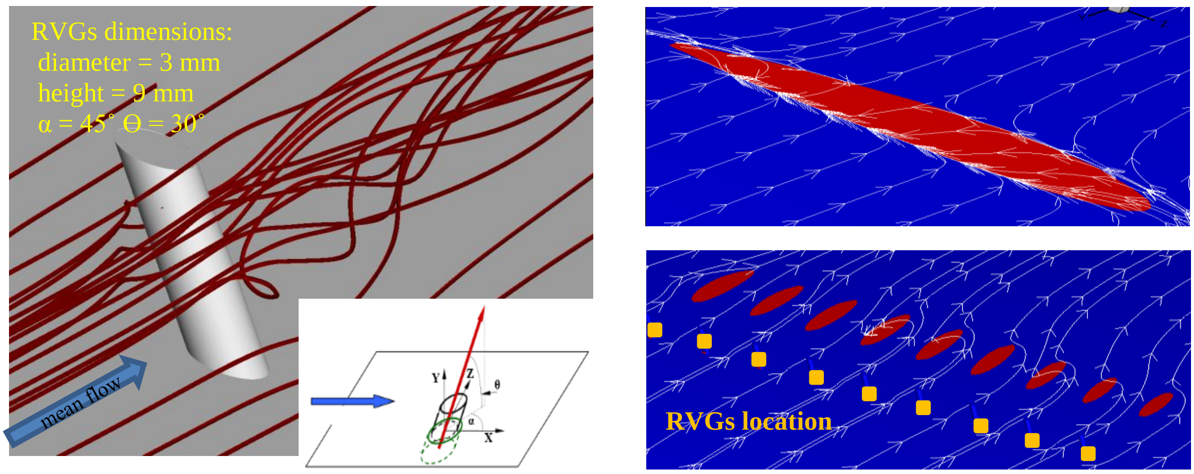

Figure 2. Streamwise vorticity creation of single RVG (left). Comparison of separation bubble (right)