Chapter 9

CONCLUDING REMARKS AND FUTURE WORK

Flapping propellers have received recent attention as a quiet and efficient alternative to traditional screw propellers for use in AUVs. Part II of this thesis has focused on the study of the maneuverability properties of a caudal-fin-type propeller that can perform large rotations in all three degrees of freedom. Employing an experimental optimization procedure, the parameters of the optimal trajectory that generates a specified side force have been obtained, with optimality being defined as maximum geometrical efficiency. Chapter 7 has considered the effect of aspect ratio on the resulting optimal trajectory. A fin of AR=4, that corresponds to the efficient lift-producing fins of thunniform swimmers, was considered. The resulting optimal trajectory presented and efficiency double of that of the optimal trajectory for a fin of AR=1 and is dependent on the use of high three-dimensionality and large rotations, which explains its absence in nature. The effect of introducing a degree of compliance on the fin's performance was evaluated in Chapter 8 and shown to be detrimental to the maneuverability efficiency, although the target force was achieved.

These results demonstrate the potential of employing a caudal-fin inspired propeller for the maneuvering of AUVs. A considerable amount of research, however, remains to be performed to fully characterize the performance of such a mechanism. In terms of the obtained results, a full understanding of the optimal trajectory would require a quantitative measurement of the flow and vortex features employing techniques such as 3D PIV, as well as the tracking of the fin deformation in the flexible case. Because a global optimum is not guaranteed, it would be beneficial to perform several repetitions of the optimization procedure with varying initial conditions. This is especially the case for the flexible fins, whose optimization was initiated at the optimal trajectory for the rigid fin. Although the strategy followed by the rigid fin is extremely efficient, causing the fast convergence of the flexible fins, it may be the case that a completely different strategy could result in an improved performance in the flexible case. In addition to the aspect ratio, the morphology of the fin has been proven to be an important factor in the performance of animal locomotion; experiments that consider the effect of the fin's shape will undoubtedly yield interesting results.

Several additional aspects related to the performance of the system when attached to the underwater vehicle have not been considered. The current experiments have been performed in an oil tank and correspond to the maneuverability of the AUV at rest. In most cases, however, the vehicle will need to perform maneuvers when it is in motion. The implementation of similar experiments in the presence of a co-flow are therefore an important step towards the development of a fully functional mechanism. In this direction, the interaction of the AUV body with the fin should be considered, both in terms of the modifications it produces in the incoming flow and its inertia and corresponding added mass when generating turns. Combining these two steps, the final objective would be to test a full AUV that is free to move within the tank. This final step is vital to the evaluation of the maneuvering performance, because, even though the average force in the y' direction is zero by definition, the composition of rotations during the maneuver may still provoke a final overall turn in an undesired direction. Considering a different measure of efficiency in the performance of the optimization may also be conductive to a reduction of these detrimental turns.

In conclusion, this research has shown the effectiveness of introducing high three-dimensionality and high rotations in the maneuvering performance of a high-aspect-ratio caudal-fin type propeller. Because high-aspect-ratio propellers are known to result in higher propulsive efficiencies, the mechanism investigated in this work shows promise as an efficient and quiet combined maneuvering and propulsive system for AUV use, that eliminates the need for additional surfaces or mechanisms and allows the utilization of a rigid main body.