Weak solutions for the motion of a self-propelled deformable structure in a viscous incompressible fluid

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The understanding of swimming or flying is one of the main challenges in fluid dynamics. This problem has been considered by many scientists for a long time: for instance around 350 BC, Aristotle was already writing observations on fish and cephalod locomotion.

A possible common starting point for studying how fishes or micro-organisms swim or for studying how birds or insects fly is to consider the classical Navier-Stokes system for the fluid dynamics. For the dynamics of the creature, which swims or flies, there are many possibilities but it is reasonable to consider it as a deformable structure. However, this deformation, which allows the creature to swim or fly, depends a lot of the regime of the fluid. The strategy for low Reynolds number flow is quite different from the one for high Reynolds number flow. Moreover this deformation depends also on the creature considered (for instance fishes and cephalods are not swimming in a similar way). A first approach, which was considered in [2] was to assume that the deformation of the creature is given whereas its position (i.e. its center of mass, its orientation) remains unknown. The corresponding model was also studied in [2] where the existence and uniqueness of strong solutions was proved.

We deal with a model of swimming where we consider that the muscles of the creature are strong enough to perform a given deformation. We therefore consider that we can impose a deformation for the structure, but since the position of the structure (center of mass, orientation) remains an unknown of the system, the problem is still a free boundary problem.

The aim of using such a model is to investigate the self-propelled motion in a viscous fluid which can be seen as the following control problem: can we control the position of the fish by using its deformation as the control? Before considering such a problem, it is important to first have some well-posedness results.Using penalization we prove the existence of weak solution, see [1].

References

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