A model of oar-boat-rower system to optimise rowing performance

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1. Introduction

Among all the sports that require a high muscular power level, rowing is probably the one that requires the most accomplished technicality for exploiting that power. Indeed, an elite rower can be defined as an athlete who has got high muscle power and also has trained himself to manage that power in an optimal way, the performance indicator being the necessary time to run a 2000 m. The performance depends on many parameters, as Baudouin and Hawkins (2002) highlighted in their analysis and Soper and Hume (2004) in their literature review. Since many parameters are concerned, the optimisation of performance is not possible just by repeating experiments with variable settings. Consequently, it is appropriate to try to build a complete model including all the parameters originated from mechanics, hydrodynamics and biomechanics. The model would help to evaluate the performance sensitivity to the parameters. Due to the blade propulsion and to the rowing technique with a sliding seat on the boat, the movement of the boat is naturally an unsteady movement on the water. In this first approach, we insist on the biomechanical aspects with a personalised model including 32 anthropometric parameters obtained on a French elite rower.

2. Methods

The model has been developed using Adams software devoted to rigid mechanics. For the biomechanical part, the Plugin Life MOD has been used. This permits the access to anthropometric data such as GEBOD (Cheng et al. 1994) leading to the rather fast generation of rower biomechanical models. The biomechanical skeletal consists of 19 body segment and 18 joints (Figure 1). These models can be generated at different degrees of personalisation with respect to the age, gender, weight and size.

The presented model includes also boat mechanics where the oarlock mechanical complexity is modelled with three revolute joints with non concentric axes. All the settings parameters are adjustable to match all rower morphology, but only the surge movement (Cabrera et al. 2006) of the boat is considered in this first approach.

For hydrodynamics, a simplified drag force is introduced for the blade-water and boat-water interactions.

The internal kinematics of the boat is here controlled: the three oar rotations, the sliding seat translation and the lower torso rotation on the seat. Then, the rower kinematics is computed with passive joints using viscoelastic behaviour adjusting stiffness and damping at each joint. The kinematics results are then discussed with the training staff and input control variables are varied according to the trainers' expertise.

3. Results and discussion

The simulation leads to the evaluation of inertial effects between boat and rower, displacement of the mass centre of the rower, hydrodynamics mechanical actions (Caplan and Gardner 2007; Hill and Fahrig 2008) and velocity of the boat. The latter is plotted in Figure 2. Calculated and measured velocities are found in rather good agreement, hence showing an encouraging sign for a more sophisticated model.

This complete and complex model of the oar-rowerboat system establishes the basis for future rower style optimisation. The first simulation results presented here show the potential offered for future studies on rower technique optimisation. Moreover, these first simulations and experimental measurements obtained with an instrumented boat are found to be in good agreement and allow us to be confident on this model.

This method allows computing first simulations but needs to be coupled with an accurate rower motion analysis. Indeed, the rower style has to be precisely defined and analysed to be correctly introduced and controlled in the model. Moreover, it will be necessary to measure the

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Figure 1. Skeletal representation of the rower issued from ADAMS software.



Figure 2. Comparison between model and measurement.

rower external actions in order to determine torque at each human joint during the stroke and thus estimate the power consumption corresponding to each style.

4. Conclusions

ADAMS permitted to build a multi-body dynamic model of the boat equipped with virtual setting devices which allowed the model to match any rower morphologies. The oarlock kinematics was modelled with a high realism taking into account the three non-concentric rotational axes. It is to be noted that friction and flexible oars could be introduced to obtain more parameters for optimisation studies. Although the hydrodynamic models used here for boat-water and blade-water interactions were simplified at this preliminary stage, the model of the whole 3D system includes all the fields involved in rowing: mechanics, biomechanics and hydrodynamics.

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References

- Baudouin A, Hawkins DA. 2002. Biomechanical review of factors affecting rowing performance. Br J Sports Med. 36(6):396–402.
- Cabrera D, Ruina A, Kleshnev V. 2006. A simple 1⁺ dimensional model of rowing mimics observed forces and motions. Hum Mov Sci. 25:192–220.
- Caplan N, Gardner T. 2007. Modeling the influence of crew movement on boat velocity fluctuations during the rowing stroke. Int J Sports Sci Eng. 1(3):165–176.
- Cheng H, Obergefell L, Riser A. 1994. Generator of body (GEBOD) manual., AL/CF-TR-1994-0051, Armstrong Laboratory, Wright-Patterson Air Force Base, Ohio.
- Hill H, Fahrig S. 2008. The impact of fluctuations in boat velocity during the rowing cycle on race time. Scand J Med Sci Sports, DOI: 10.1111/j.1600-0838.2008.00819.x.
- Soper C, Hume PA. 2004. Towards an ideal rowing technique for performance, the contributions from biomechanics. Sports Med. 34(12):825–848.