OPTIMAL ARM STROKE FOR COMPETITIVE FREE STYLE SWIMMING

[1] Shinichiro Ito
[1]Department of Mechanical Engineering, The National Defense Academy Japan;
email: ito@nda.ac.jp, web: www.nda.ac.jp/~itoh/

INTRODUCTION

Advancing movement of an animal in water can be roughly divided into two categories, locomotion of the maximal efficiency (the minimal energy consumption mode) for an usual motion and that of the maximal speed (the maximal thrust mode) for an urgent evacuation or a predatory action instinctively. For competitive swimming, an operation of the maximal propelling force is desirable. On freestyle swimming, forms of the operation are calculated by using equations of turtles' instinctive locomotion[1].

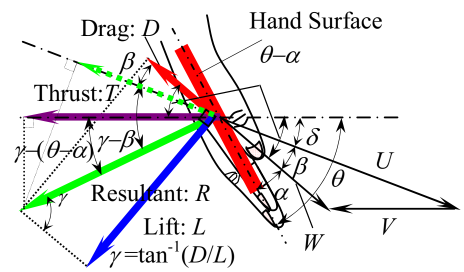
METHODS

Under a quasi-steady condition, flow induced forces of a hand change by its postures. Thrust force T is generated from a lift force L and a drag force D generated by the flow shown in Figure 1. The thrust force T is balanced with the drag force D_{DP} by the whole body in a constant swimming speed. The formulae of balance of such forces are established, and those formulae are exactly corresponded to the ones of turtles[1]. They are solved concerning the thrust force and the efficiency based on a posture of hand whose lift-drag characteristics are obtained by experiments.

Wind tunnel tests are performed with a plaster replica of a hand including a palm paddle and forearm of an excellent swimmer. As an aspect ratio changes, significant differences in characteristics of lift-drag forces appear with varying sweepback angles ψ whose convention is shown in Figure 2. Sweepback angles of the hand, ψ=135°, 90° and 45° correspond to the catch, the pull and the finish phase on freestyle stroke respectively. With the variation of sweepback angle ψ, the hydrodynamics characteristics against angle of attack α are measured in a wind tunnel with a Reynolds number which is almost equivalent to the relative inflow velocity in water to the hand of actual swimming.

RESULTS AND DISCUSSION

The maximum thrust can be obtained when θ=90°. Namely, the hand plane is perpendicular to the axis of the advancing direction. Each of the maximal points for each ψ has the angle of attack α=90°. That is to say, the hand should be driven along the body axis parallel to the advancing direction for the entire drag forces to be used. The maximal value of the coefficient of thrust at ψ=90° is 0.808, which is 6.2% larger than that at the maximal efficiency. On the other hand, the maximum efficiency η_{max} can be obtained when the motion of the palm paddle corresponds to an S-shaped pull motion. The maximal value of the efficiency at ψ=90° is 0.380, which is 7.1% smaller than that at the maximal thrust.



Driving velocity: U Advancing velocity: V
Relative velocity: W Tilt Angle of hand: θ
Angle of attack: α Driving angle: δ

Figure 1: Forces and velocities on a hand paddle

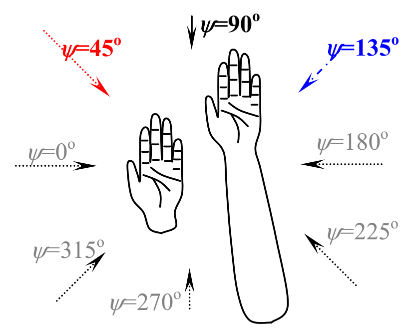


Figure 2: Hand and arm replica used in experiment and Sweepback angle ψ defined by Schleihauf[2].

CONCLUSIONS

The calculations show very interesting and unexpected results which differ from what were said conventionally. An S-shaped pull stroke, a popular form for the conventional front crawl, is resulted as a form of the maximum efficiency mode utilizing lift and drag force by hands. On the other hand, Drag type swimming is the fastest swimming form which generates the maximum thrust. It happened to coincide with the form of Ian Thorpe who has four individual world records.

REFERENCES

1. Ito, S and A. Azuma, Proc. 50th Japan National Congress on Theoretical and Applied Mechanics, Science Council of Japan, 271-280 (2001).
2. Schleihauf, R.E., Swimming III, pp70-109. University Park Press, Baltimore, MD (1979).