The Dynamic Analysis of Single Fin Swimming Technique

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Introduction

The aim of this study is to analyse the reaction forces, which arise on the single fin surfaces as a result of swimming movements. This analysis will be helpful to explanation the problem of efficiency and economics of the utilisation of forces, arising as a result of the fin movements during swimming in the order to gain the maximal speed. The large surface (0,4 m²) of the single fin enables to explain this problem in the aspects of the swimming propulsion principles. This way, it will be possible to obtain some information about the biomechanical criteria, which determine the maximal single fin swimming speed. Only Wu (1960, 1971) and Shuping (1989) studied the dynamic motion structure during the single fin swimming. Other studies are mainly based on the results obtained from analogies for fish propulsion and dolphin motions studies. [Ungerechts, 1982, 1986; Ahlborn at all, 1991; Webb, 1988; et. all] and referred to the research of kinematics parameters of swimming movements. [Colman et all, 1997,1999 Soloviev, 1993; Morales, 1998; Tze Chung Luk et. all, 1999; Szilagyi et. all, 1999.].

Methods

Forty men participated in the study. There were three groups of single fin swimmers: (senior - mean age 18,5; junior b – m. a. 16,4; junior d – m.a. 12,2). The fourth set of ten subjects was the group of senior swimmers, crawl and dolphin specialists (mean age 19,3) at the national level. They swam one experimental trial with maximal possible speed on 50 m distance, under water, using the same standard single fin. There were strain gauges glued on the both sides of single fin surfaces, in symmetry axis where the plate is connected with the boots. Impulses from sagging fin and strain gauges were amplified, converted and recorded by a PC. The sampling frequency was 20 Hz. The raw data were in the form of time-dependent signals representing the reactive water resistance force exerted on single fin surface, as the result of upward and downward movements. Time-series analysis was used in order to assess the measured parameters and their level of stability. Another analysis was made with assumption that sine harmonic is regarded as the model to optimise values and stability of parameters in the process of propulsion generation (Rejman 1997). As the result it was obtained the mean values of amplitudes of recorded forces, defined Fourier series for these values for all trial courses separately, and approximated the original time function of force by its specific sine harmonic. Finally it was possible to quantify the areas of harmonic fit between both functions using the squared difference between the approximated curves. These areas were the measure of the errors between the signals of the both functions (measure of technical structure errors). The additional procedure was made in the order to verify in empirical way the diagnostic value of the dynamometric methods. The aim of that was to measure the reaction forces of the sagging fin and video recording of the fin movements, in the same time. The main kinematics parameters of fin movements were also obtained using - video digitising methods [Colman et all, 1996], but the kinematics data were not separately analysed in this study.

Results & Discussion

The research outcomes imply (fig.3 & 4) that the high swimming speed is determined by the high stability of the forces, which arise as the result of the single fin movements. The swimming speed depends on, but is not the direct consequence, the stability of the time structure of the fin motions. The stability of the cyclical swimming movements parameters, is a main criterion of assessment the efficiency and economics of the propulsion in water, in all of swimming propulsion theory interpretations. Stable dynamic and time structure of the ocytalatory movements is the criterion of avoiding the fluctuations in momentary velocity, being the factor determining effective solution of the movement task in water [Kornecki 1979]. According to Persyn et al., (1997) the stable infracycle velocity gives the ability of using the positive aspects of inertia forces in each movement cycle, what is considered to be an important criterion of mechanic efficiency of swimming technique. The stability of the time-dynamic structure (rhythm) of the “dolphin” movements is also the measure of using the movement potential of the swimmer to develop and maintain the maximal swimming speed. [Meglischo1993]. As a result of movements of a single fin, the turbulent flow of water and vortices are evoked. The outcomes of the evoking of the vortex will be positive for the generated propulsion only in case if its structure is stable [Ungerechts, 1982, 1986; Arelano, 1999; Wu, 1960]. The results showed (fig.1, 2) that the swimming speed doesn’t depend on the maximisation of the force
involved in the movement of fin surfaces, but on the equal proportion between the forces generated on single fin surface during its up and down motions. The research on the movements of dolphins implies that the values of forces observed during the phase of the downward movement of the fin were slightly higher than the values registered in the phase of the upward movement [Ungerechts, 1982]. (And this corresponds to the results published in this paper.). The research results of the “dolphin” movements of a human being showed that the duration of phases of movements up and down is nearly identical [Arelano, 1999]. It has been also proved [Liu et al., 1997] that the coefficient of the propulsive forces reaches the maximal value as a result of symmetrical movements of the rowing surfaces in both directions. The research outcomes imply that the ability of adjusting the power, engaged in the movement, to the value ensuring maintaining the stable dynamic structure of movements of a single fin have positive influence on the swimming speed. Arelano (1998) confirmed that the competitors of a high sports level, while swimming the butterfly style, performed the movements of optimal trajectory (and consequently, power). Lyttle et al.(1999) noticed that optimal parameters of oscillatory swimming movements ensure the use of
“slide energy” and compensate for the speed losses, caused by the non-effective phases of propulsion movements. The necessity of adjusting the frequency of single fin movements to the level ensuring maintaining high stability of movements is confirmed by the results published by Yi-Ch-Pai and Hay (1988). It has been also proved (fig. 1.) that the better usage (intensification) of the upwards motions forces in the cycle structure helps to get a high single fin swimming speed. Colman et al. (1999) proved that the direction of the vortex generated during the phase of upward movement is opposite to the direction of swimming. In the consequence, the meaning of vortex is connected not only with the “delivery of additional mass” but also with initiating of the additional force, which are based on rejection. This effect does not accompany the upward movements and this is the legitimacy factor of the postulate concerning the necessity of intensifying the fin movements up and down in order to increase the single fin swimming. The technical skills of readjusting fin movements to the criteria resembled by the dynamic sine model of the ratio of the forces arisen on the single fin surfaces gets possibilities for obtaining the highest swimming speed. (fig. 5.) The following arguments confirm the legitimacy of acquiring the sinusoidal function as the model of distribution of dynamic and time parameters of single fin movements, which are measured by the dynamometry method. The parameters of the description of the technique of single fin movements, constituting the object of the research (frequency, periodicity and amplitude of forces generated cyclically on the fin surfaces) are the variables allowing for respective relating the examined courses to their mathematical, sinusoidal equivalents. The previous research led to the conclusion that high speed of swimming of dolphins (and human being also) is a result of, among others, harmonic propulsion movements [Ungerechts, 1982]. This is proved by the fact that the movement amplitude in particular cycles of fin movement determines their duration and thus affects the frequency of the movement [Ross, 1995]. Furthermore, there is an inversely proportional relation between the force of sagging of the fin surface in reaction to water resistance and the movement frequency [Shuping, 1989]. The harmonic function equation also determines the stability of mutual relations between the dynamic parameters of fin movements in the time function of covering the distance [Rejman, 1997]. Another way to legitimate the above statement are the results of the research in kinematics parameters of single fin swimming [Tze Chung Luk et al.,1999; Szilaggy et al., 1999; Colman et.al.,1999]. These results correspond with the ratio of velocity parameters obtained in this study. The form of the velocity curves (the horizontal velocity of CM and the vertical velocity of the fin tail) are very similar (fig. 6.). The horizontal velocity of CM and the vertical velocity of the fin tail) are very similar. Additionally, sinusoidal form of the recording resultant forces signals end the sinusoidal curve of vertical velocity of the fin are the straightness illustration of the base hydrodynamics principle that the increment of the reactive resistance forces is the function of the square increment of the single fin movements velocity.

Selected References


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