SOME MECHANICAL PROPERTIES OF THE FIN SWIMMING FIN

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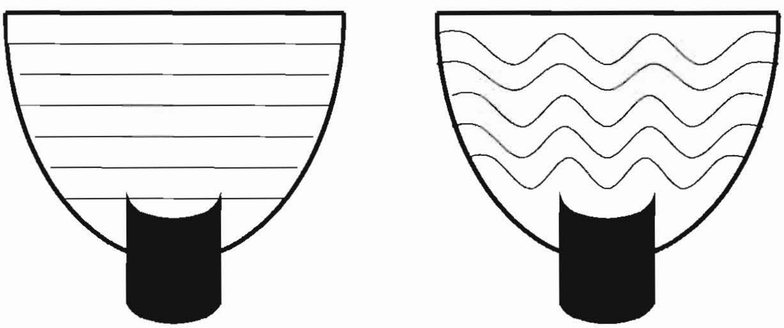
The fin is a powerful propelling tool in fin swimming. The purpose of this study was to explore ways of quantifying the mechanical characteristics of fins so that future work can establish the relationships between these characteristics and performance. Measurement of natural frequency, deflection, and transfiguration under water might provide some valuable reference parameters for developing a more efficient fin.

KEY WORDS: fin, mechanical measurements, fin swimming.

INTRODUCTION: The main thrust in fin swimming comes from undulating the fin. For similar ability levels, the quality of the fin would be the main factor affecting the final result of competition. Most fins used in competition are made of composite laminate glass-fibre. There are around 20 layers in a fin plate. The shape of the fin plates is generally based on 'feeling' and experience. Usually, the fins are cut into a shape resembling a fish tail (Figure1). Some of the layers may be partly peeled off according to individual preference. The thickness of a fin is changed gradually from the head, the end with foot covers, to the tail end. Thus, a fin normally has two asymmetric sides: a reconstructed side and a non-reconstructed side. In fin swimming, the reconstructed side always faces down. Because fins are reconstructed in different ways a set of mechanical measurements is required that provides useful information for improving their design. According to swimmers and coaches, a good fin should be: a) highly elastic, b) light in weight, and c) resistant to mechanical fatigue. It is apparent that the above requirements could be represented by the mechanical parameters of the fin.



(a) (b)

Figure 1. Two typical reconstructed sides of fins. The lines show the layers' edge of reconstruction layers. (a): Beeline edges, (b): Waved line edges.

METHODS: Four fins used by four international level fin swimmers (short distance) were used as test specimens. Three of them, Fin I, II and III, were made by the same company. Fin IV came from another company. The measurements of the fin's mechanical properties were natural frequency, deflection and transfiguration under water. Natural frequency is syntony frequency. To measure the natural frequency an 'impact' method was used. Two electrical-resistance strain gauges were adhered to the non-reconstructed side along the centreline of the fin. The centreline is perpendicular to the tail edge line of the fin. The distance between two gauges at points A and C (Figure 2) was 30cm. The distance of one gauge to the tail end edge of the fin was 11.5cm. Thus the other one was 41.5cm from the tail end edge of the fin. The natural frequencies were measured in two different fin fixation conditions. In the first a human foot model, made from wood, was fitted into the fin's foot

cover. In the second a subject wore the fin and stood at the edge of test platform during measurement.
The displacement of the reconstructed side under load was measured. The loads were added at point A and C respectively. The loads ranged from 0 KgF to 2.5 KgF. The displacements of points A, B, the midpoint of AC, and C relative to the original position were measured. Thus a range of bending moments (in Nm) and the corresponding deflections (in m) calculated for each fin.

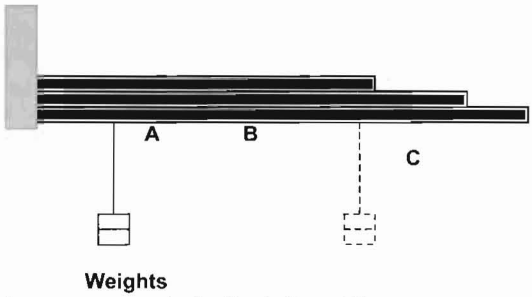


Figure 2. Deflection measurement of a fin. A, B and C were measurement points. A and C were also the load points. The longest layer represents the non-reconstructed layer.

The fin is an elastic plate. In response to kicking the fin is displaced up and down relative to its unloaded position. Two variables, fin transfiguration coefficient (FTC) and fin transfiguration rate (FTR), were used to describe the bending of fins. The fin transfiguration coefficient indicates the magnitude of a fin's transfiguration. The distance of the middle point of the line between the foot cover's tips and the middle point of the end edge of the fin is defined as D. D is a maximum (D_0) when the fin is not bent and is a minimum when the fin has the greatest bending. The fin transfiguration coefficient (FTC) was calculated as:

$$FTC = [1-(D/D_0)]\times 100\%$$

The fin transfiguration rate (FTR) was defined as the rate of change of D

$$FTR = D/t$$

D, FTC and FTR were measured and calculated from underwater video of swimmers performing their maximum effort for 100 meters. The recorded section was 25-35 meters from the start line. The camera speed was set at 100 fps.

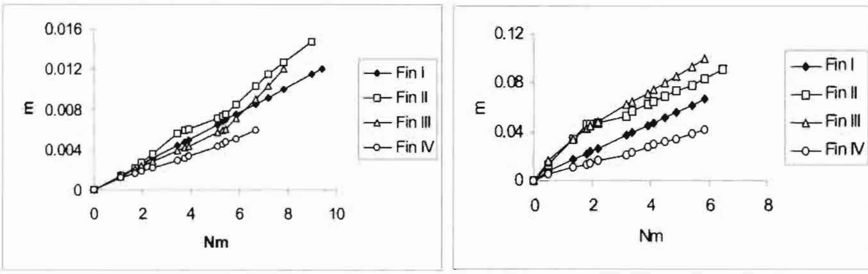
RESULTS AND DISCUSSION: Table1 shows the natural frequencies of four fins under different fixation condition as well as different impact points. In the model fixation, A and C were the result of impact points at A and C respectively.

Table 1. The Natural Frequencies under Different Fixation Conditions and Impact Points (Hz)

		Fin I	**Fin II**	**Fin III**	**Fin IV**
Model fixation	**A**	3.87	2.75	3.56	5.75
	C	3.80	2.80	3.56	5.75
Foot fixation		3.40	2.84	3.33	5.17

The value sequence of natural frequencies from high to low was Fin IV, I, III and II. The relative values of natural frequency were constant. These values were unrelated with the impact points. We can find that fixing the fins by means of artificial foot model is a good approach to the human foot.

Figure 3a shows deflections of point A under loading at point A and figure 3b deflection of point C under loading at point C. In both cases Fin IV had the smallest deflections and Fin I the second smallest at the high end of the loading range. Fins II and III deflected more than Fin I and Fin IV at the high end of the loading range. The deflection behaviour of FIN I was very linear. That is, a given increase in bending moment produced a consistent increase in deflection. The deflection of Fin II and Fin III was less consistent than Fin 1.



(a) (b)

Figure 3. Selected deflection curves (a): Deflection of point A under loading at point A (b): Deflection of point C under loading at point C.

Table 2 shows the maximum fin transfiguration coefficient (FTC) and fin transfiguration rate (FTR) during fin swimming. Fin I had the smallest fin transfiguration coefficient and largest transfiguration rate. This is interesting given that the deflection curves and natural frequency indicated that FIN I was intermediate in stiffness.

Table 2. Fin Transfiguration Coefficient and Fin Transfiguration Rate.

	I	II	III	IV
FTC (%)	14.5	22.1	23.1	19.3
FTR (m/s)	2.41	2.37	2.06	2.25

CONCLUSION: This study has indicated that measurement of mechanical properties of fins in terms of natural frequency, deflection under loading, transfiguration coefficients and rates during swimming may provide insights towards designing fins top optimise fin swimming performance. The next stage of investigation will be to investigate the relationships between the mechanical properties of the fins and performance in terms of thrust from the fins and swimming speed.

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