DEVELOPMENT OF AN UNDERWATER PLATFORM FOR MEASUREMENTS ON ALL COORDINATE AXES FOR BIOMECHANICAL APPLICATIONS

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INTRODUCTION: Hydrogymnastics is a recent physical exercise method which has been considered less harmful to the body. Its use has been increasing and so the need to better evaluate its effects. The objective of this work was the development of a force platform for the measurement of forces and force moments related to the three orthogonal axes for underwater biomechanical purposes. The development was focused on applications related to hydrogymnastics and for this specific use, the design had to consider waterproofing and high sensitivity.

METHODS AND PROCEDURES: The Lywood et al. (1987) force platform for small three component forces was chosen as a starting point model. It is a strain gauge instrumented beam structure intended to measure forces but unable to quantify torques. A new design concept was used in this work in order to measure all components of force up to 4000 N and force moments up to 800 N.m with a 2 N and 0.4 N.m sensitivity respectively. The finite element method was used to determine the best gauge positioning. Four electrical strain gauges in a full Wheatstone bridge assembly were bonded to a steel beam structure subjected to bending stresses for each component of force or force moment. A total of 24 gauges per platform were used so outputs were completely independent of each other; thus mathematical operations on signals concerning channel separation were unnecessary. Signals were as usual amplified and filtered. Data processing was computer based on a 160 KHz PC machine via a 12 bit A/D converter. Criteria such as very low cross-talk, high underwater sensitivity and high natural frequency with respect to the maximum measurement frequencies were taken into consideration. By cross-talk is meant an undesirable signal measured in a given direction when a force or a moment is acting in a different one. Cross-talk was minimized in two different ways: a) gauge bonding on sites of maximum strain for a given direction while null with respect to others; b) irrespective of strain magnitude, gauge distribution on the bridge was such that undesirable strains canceled out. Higher sensitivities are obtained for larger beam bendings, but in this case the system natural frequency is lowered, and this is an undesirable effect. The ideal case would be high sensitivity associated with stiffness in order to increase the natural frequency, since stiffness is linearly related to the square of the natural frequency. Since sensitivity is inversely related to stiffness, this ideal case is not attained. The finite element method was able to provide the better compromise solution.

Waterproofing was achieved through internal positive pressure. The platform was sealed and kept under pressure, thus the vertical force component was linearly affected by this pressure. Since overall response was linear, force generated by the internal pressure could be easily compensated, acting on the system baseline. The platform structure showing sites of gauge bonding can be seen in Fig. 1 and an schematic view of the whole system in Fig. 2.

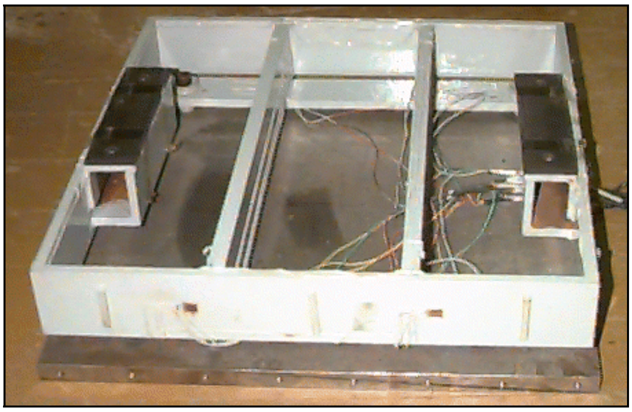

Figure 1 – Force Platform Structure showing 2 strain gauges attached to the lateral beam.

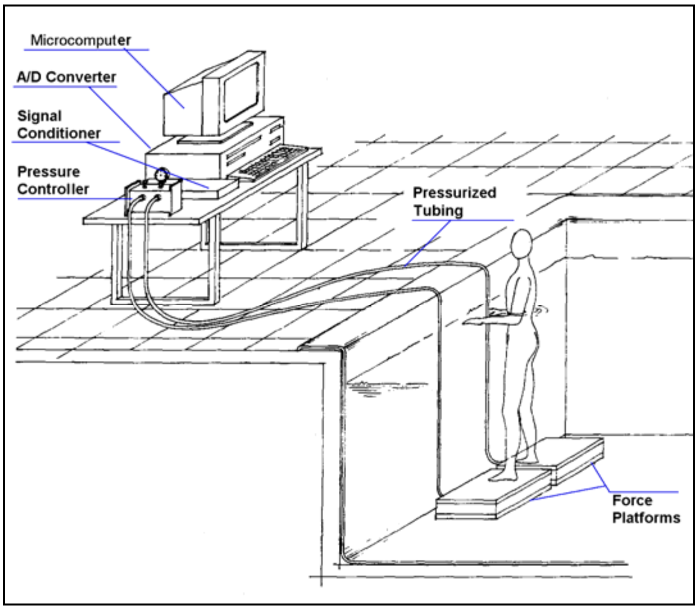

Figure 2 – System setup for platform and accessories

RESULTS AND DISCUSSION: According to theory, beam structure should provide a linear response. In fact, static calibration demonstrated that linearity was within 1%. According to Roesler (1997), platform static calibration and linearity deviation were less than 1% and cross-talk less than 2%. Dynamic tests showed that the platform fundamental frequency was 35 Hz. Physical exercises were done by an athlete inside and outside the pool. Figure 3 shows an athlete during hydrogymnastics over the force platform. Figure 4 and Figure 5 shows platform response in terms of the vertical force component for a high frequency exercise. Even in this case, the higher excitation frequencies were near 6 Hz. This response is shown in the time domain and frequency domain respectively. Signal analysis in the frequency domain showed that the system is reliable for underwater applications.

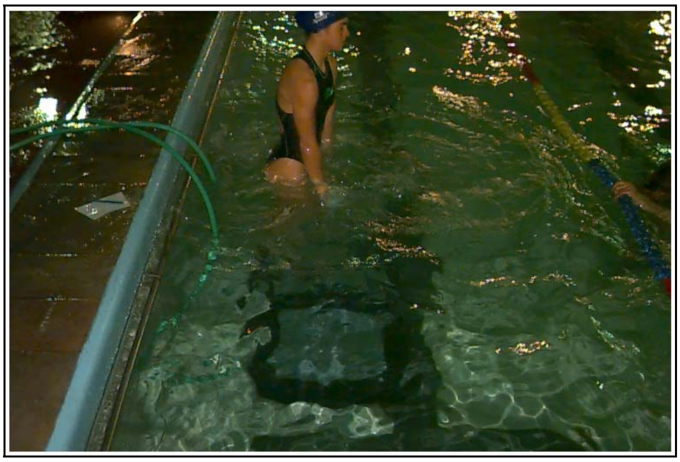

Figure 3 – Hydrogymnastics over force platforms

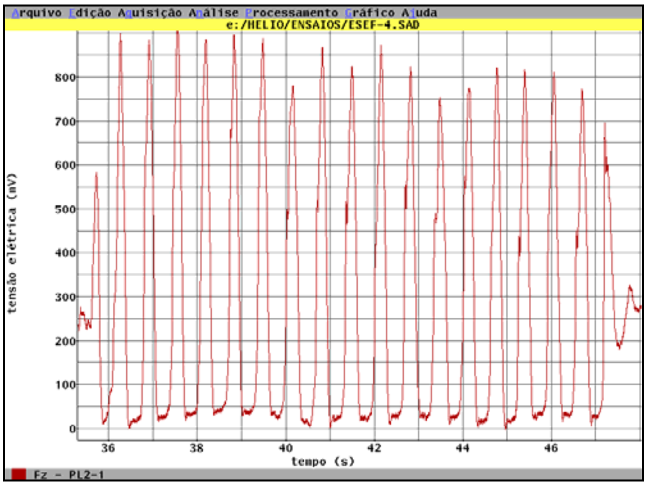

Figure 4 - Electrical response of the force platform in terms of the vertical force component before calibration, while practicing a high frequency exercise.

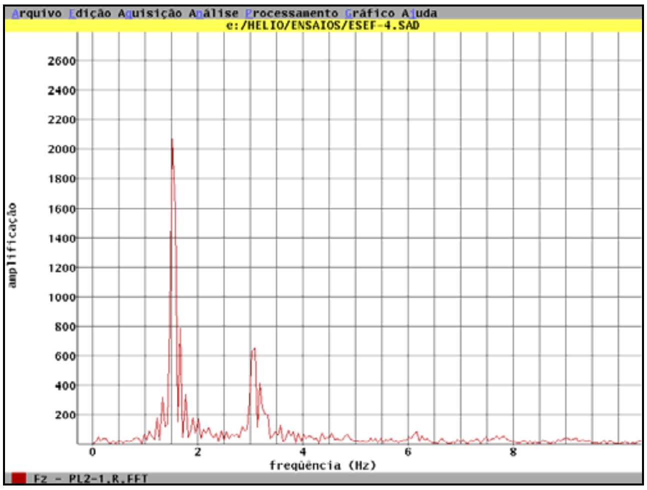

Figure 5 - The same response as in Figure 4, in the frequency domain.

Calibration results including frequency domain analysis and tests done with an athlete inside the pool showed that the platform is reliable and thus can be conveniently use in underwater applications.

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