

## **DEVELOPMENT OF A COMMERCIAL ANALYSIS SYSTEM DESIGNED TO ENHANCE PERFORMANCE OF ELITE SWIMMERS IN STARTS, TURNS & RELAY CHANGEOVERS.**

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This paper will provide information concerning the development of the PAS-S swimming start, turn and relay changeover analysis system, designed to enhance the performance of elite competition swimmers. The objective of this project was to provide a system that is able to be retro fitted into almost any training pool. A predecessor of PAS-S was the Wetplate Swim Analysis system which was developed at the Australian Institute of Sport in a pool specifically designed to accommodate it. The Wetplate System proved to be invaluable in the preparation of elite Australian swimmers for international competition in starts, turns and relay changeovers. However, replicating Wetplate at other training facilities was therefore not an option. This project was initiated to develop the PAS-S analysis system that may be installed to the advantage of swimmers in almost any pool.

**KEYWORDS:** Swimming, Analyses, Technique Coaching, Starts, Turns, Changeovers

**INTRODUCTION:** Sprint races in competitive swimming are often won by hundredths of a second and in distance events by less than a second. Better starters are often 0.5 seconds better than poorer starters over the 15m length that denotes this recognised start distance. Races in competitive swimming have a turn every 50m in long course events and every 25m in the short course events. In the 1500m long course event, there are 29 turns and 59 in short course. Small time differences in tenths of a second per turn occur frequently between better turners and not so good turners. Thus, it becomes obvious how important it is for competitive swimmers to get the most out of every start and turn in competition as it may make a considerable difference where the swimmer places in international competition races. The Wetplate Analysis system (2012) was developed at the Australian Institute of Sport (AIS) in 2006. It was established as a vital component in a new training technology pool with the objective to better prepare members of the Australian swim team for international competition. As the planning of the new pool incorporated the requirements of the Wetplate system, this then limited the possible duplication of the Wetplate system in other already established pools, without performing extensive modifications to the pool's structure.

The AIS technology pool incorporated under water windows at specific locations to enable the underwater filming required for Wetplate analysis. The Wetplate system also required that the instrumented turning wall to be installed within the existing pool wall structure at the starting end of the pool, with its front surface in line with the neighbouring wall. There was also a requirement to strongly affix the instrumented starting block on the pool deck, in place of the pool's regular starting block, at the starting end of the pool in line with the centre of the third lane. Wetplate also had the capacity to utilise a magnetic timing system which would accurately provide the instant the swimmer's head passed the distances 5m, 7.5m, 10m, 15m and 20m from the starting wall. This required the necessity to have vertical structures within the pool that incorporated magnetometers on either side of the third lane at these specific distances. The vertical structures also needed to be able to be lowered so as to lie on the pool's floor when not required. All magnetometers needed to be connected to the main Wetplate computer through electronic cables that traversed down the length of the pool within a channel in the pool's floor that was located in the centre of the third lane. The vertical post structures which housed the magnetometers were raised when needed by way of utilising compressed air. There was also a series of synchronised 50hz video cameras at the various distances located high on the pool building's wall with a perpendicular view of lane three. These video cameras were used to also manually assess when the swimmer's head passed the various distances. As the pool was dedicated to providing swimmer performance enhancement, the Wetplate system was able to be prepared for testing in approximately sixty minutes prior to the commencement of the testing. Feedback to the swimmer could be

provided almost immediately the swimmer executed the start or turn trial after exiting the water. While the swimmer was provided with feedback, another swimmer was able to be tested with the Wetplate system. This was possible as the Wetplate capture computer saved the captured information from each trial, including visual images from the cameras, timing information from the timing system and starting signal, as well as analogue force signals from the starting block and turning wall, on an independent computer server. All the information about the trial could also be accessed immediately by the feedback computer located on pool deck.

The purpose of developing the Wetplate start and turn analysis system was to accelerate the learning process in refining a swimmer's performance in these skills. Such analysis only became possible after the development of machine vision cameras and modern high speed computers. The Wetplate system provided the coach with an immediate biomechanical feedback capability, together with an associated continuous visual image of the performance. It also provided the ability to readily compare an analysis of the start or turn performance in two separate independent trials of the same or different athlete.

**METHODS:** The AIS completed the developed of the Wetplate analysis system in 2006. The Wetplate system incorporated an instrumented starting block and included a force platform that was used as a turning wall, which was mounted in a vertical orientation and was partly submerged under the water. The Wetplate starting block was comprised of a steel structure whose top surface was a modified 900mm by 600mm Kistler force platform. The force plate was angled, as per FINA regulations, down in the direction of the pool water. Under the front edge of the platform a bar was located that was gripped by the swimmer's hands during starts. The bar was instrumented on either side of the handle so as to measure the combined hand force exerted during starts. There was also an inclined kick plate that attached on the top surface of the start block force platform that was used by the rear foot during starts. The inclined kick plate setup was compliant with FINA regulations. The inclined kick plate was also instrumented with 4 tri-axial force transducers in the formation of a miniature force platform. The inclined kick plate was able to be moved up and down the starting block, to replicate its placement on a regular starting block. The weight of the Wetplate starting block was in excess of 350kg and required a specialised lifting/lowering device. The turn wall was also a modified Kistler 900mm by 600mm force platform that fitted into a section of the pool end wall that was normally filled with a dummy plate. The front surface of the instrument wall had a multitude of holes so as to minimise much of the force signal produced by the wave which travelled in front of the swimmer, so that much of the wave's force was dissipated through the holes and not measured. The forces exerted by the hands and feet in turn trials were measured directly on the turn wall. Because all but 300mm of the 900mm length of the wall was located under the water, the instrumented wall was only able to stay setup in the water for up to eight hours. For backstroke starts there were handles that attached to the main starting block force platform. The forces exerted by the hands and arms to raise the body out of the water during backstroke starts were measured by the force platform that was the top surface of the starting block. The turn wall was utilised to measure the force exerted by the feet and legs during the backstroke start. Signals from all force transducers were transferred by way of cables to the computer via amplifiers and an analogue to digital board. The PAS-S system starting block consisted of two separate specially build force platforms attached to the top surface of an anodised aluminium starting block structure. The width of the force platforms and hence starting block was 520mm and the length of the front platform was 411mm and the rear platform was 369mm. Both force platforms have inbuilt amplifiers. The inclined kicker footplate was attached to the rear force platform. The kicker footplate was not instrumented as all rear foot force measurements were obtained from the rear force platform. The inclined footplate could be moved along the rear force platform to comply with FINA regulations. A bar under the front of the forward force platform was used to measure the hand force of the starter. Due to improved construction techniques of the force platforms and as the block structure was composed of aluminium, the PAS-S starting block could easily be moved and installed in position by just two adults. The PAS-S instrumented turn

wall plate is composed of carbon fibre with a series of holes to dissipate the wave force. The Wetplate turning plate weighed in excess of 250kg and therefore had to be lifted/lowered into position with a specialised crane device. The PAS-S turn plate was able to be lifted and locked into position by two adults. The PAS-S turn plate however does extend into the lane by approximately 2cm but because of its structure may remain in the pool for long periods.

In start trials both Wetplate and PAS-S systems utilise a start button that initiates the start signal. This is triggered by a starter who stands behind the starting block. The signal from this button is also transferred by an electrical pulse to the Wetplate and PAS-S computers via an analogue to digital board.

A red LED beam across the front of the start block is used to indicate when the swimmer leaves the block in start trials with the Wetplate system. The swimmer's feet block the beam prior to the swimmer leaving the block. The instant the swimmer leaves the blocks in starts with the PAS-S, is computed utilising the force signals from the starting block.

In relay changeovers, the in-swimmer touch is detected by a modified normal touch pad in the Wetplate system whereas with the PAS-S, the touch is detected utilising the force signals from the turn force platform.

In the Wetplate system four Gig E Pulnix Machine vision cameras are used to provide visual feedback of a trial. All cameras are synchronised to run at 100 frames per second. The camera views cover the lateral or side view from behind the start block out to the 15m distance from the wall. One camera films the side view from above water to capture the above water activity during a start and turns in that area surrounding the block. The other three cameras are located in the underwater pool surround area and are located behind underwater windows. They cover the entire underwater view from the turn wall to 15m out from the wall. When viewing the visual display from a trial, all four cameras provide what appears to be a continuous image of the trial performance on the computer screen. In the PAS-S system five AVT (Allied Vision Technologies) Mako223C machine vision cameras are used. These are located at 1.5m, 5m, 10m and 15m distances out from the wall in specially engineered underwater Kistler housings. At the 1.5m distance both an above and underwater camera are located. The cameras attach to the side walls of the pool by speciality Kistler devices. These PAS-S cameras are synchronised to run at 100 frames per second and cover an image of the trial performance of the swimmer's lateral view from a position just behind the starting block to about the 17m distance out from the wall.

In the Wetplate system there is both a magnetic timing system and a manual video camera timing system which are used to identify when the swimmer's head passes through the 5m, 7.5m, 10m, 15m and 20m locations from the wall. In the PAS-S system this information is achieved immediately after the trial is complete by indicating when the swimmer's head passes the 5m, 7.5m, 10m, 15m distances from the wall by viewing the video footage and indicating when the head crosses a line on the image. This is easily done in the PAS-S system provided the system has been calibrated prior to the testing session commencing.

In the Wetplate analysis as well as the visual image from the four Gig E cameras, there is also another image provided. This image is videoed by cameras that film from a moving trolley that travels along the side of the pool and which is powered by a golf buggy. The trolley runs smoothly on rails that are situated below the surface of the pool deck. The camera trolley stays level with the swimmer. This provides a split image that combines the view from two cameras, one above and one below the surface of the water.

**RESULTS:** Both the PAS-S and Wetplate analysis systems collect the information from all sources and provide the completed analysis within minutes of the trial being conducted. The computed analysis data information may be stored on a network server computer so that feedback can be conducted elsewhere, but is usually presented on a large plasma screen with the analysis being controlled by a laptop computer on the pool deck and away from the capture computer. At the same time, the capture computer may be collecting information from another trial, enabling several swimmers to be tested during the one session. When viewing the analysis, the visual information from the machine vision cameras is always

available to be displayed. Other kinetic and kinematic analysis information can also be provided by way of switching it on or off via a selection tab. The other analysis information included in the kinetic analysis is the time history of the vertical force, horizontal force, grab bar force, rear plate force and resultant velocity of the centre of gravity (CoG) of the swimmer in both the vertical and horizontal directions. As well as the force graph, a power graph may also be displayed. The force vectors may be displayed over the visual image of the swimmer on the starting block or turning wall during the visual replay of the trial. As the indicator time line moves along the graph, the visual image is incremented accordingly, a frame at a time and moved either manually or automatically. Once the swimmer leaves the block, the force graph is replaced by a displacement and velocity graph which indicates the velocity and displacement from the wall in sequence with the visual image being displayed. Also displayed on the visual image is the leave block time and the velocity achieved during starts and the impulse achieved during turns. In starts, the distance of subject entry into the water out from the wall, the size of the entry hole, as well as the angle and velocity of entry are superimposed over the visual display. During the underwater phase of the start or turn, the time, displacement and depth are provided at the location of maximum depth as well as time and displacement at break out. A theoretical trajectory of the swimmer's path is also provided. There is also an information box which provides information concerning each trial. For starts this includes: Time to 15m, Time on block, Take off horizontal velocity, Take off vertical velocity, Angle of CoG on leaving block, Average power and Peak power. For turns it includes: Turn time, Foot contact duration, Foot contact depth at maximum force, Direction of maximum force, Average power during foot contact, Peak power during foot contact as well as total time on the wall. One of both the PAS-S and Wetplate's greatest attributes is its ability to display the analysis of two trials at the same time, synchronised by starting signal for starts or by wall contact for turns. This then provides a comparison between the one athlete at different times or of two different athletes.

**DISCUSSION:** This paper has discussed the purpose, the structure, the capabilities and the analyses that are provided by both the PAS-S and Wetplate computer analysis systems. Both these systems provide a very advantageous environment when the coach provides immediate feedback to the swimmer. The two major attributes of both systems are their ability to provide a comparison analysis of two different trials on the one screen and their capability to provide almost immediate feedback. The immediate feedback enables the coach to identify inefficiencies and try various solutions as well as to objectively assess the effectiveness of these solutions from further trials. One major advantage of the Pas-S is that trials may be exported and shared with other establishments that have a Pas-S system.

**CONCLUSION:** This paper provides an example of a modern swim specific biomechanical analysis tool, the PAS-S system, which when used in elite competitive swimming training is able to provide performance enhancement information for an elite swimmer's starts, turns and changeovers. In relay changeovers the initiating point is the touch on the wall by the incoming swimmer and other than that, the changeover analysis is similar to the start analysis. The PAS-S system is however able to be installed in almost every training pool.

#### **REFERENCES:**

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