AERODYNAMICS PERFORMANCES IN SPORTS

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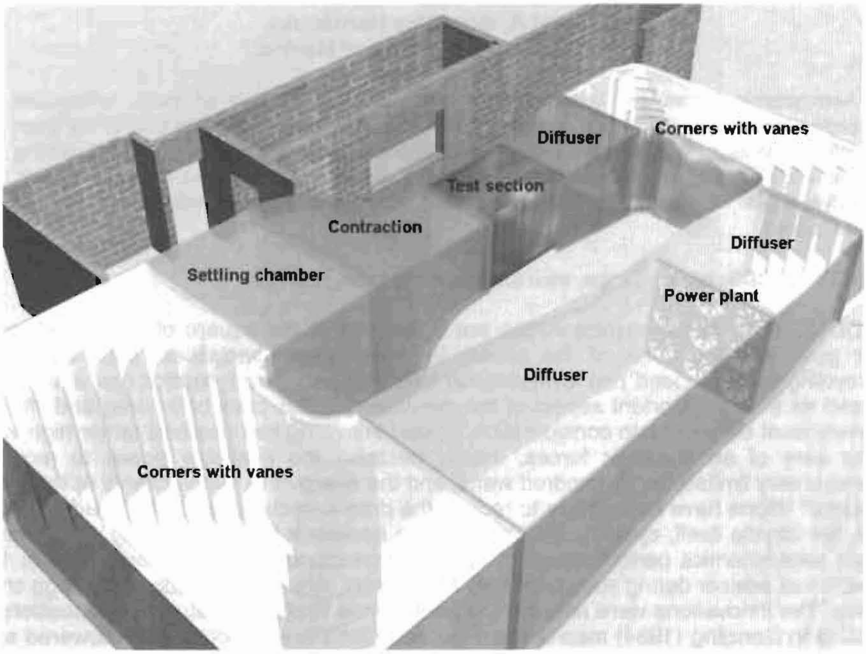
Aerodynamic forces are important in many racing sports and all those which use projectiles or any kind of ball. For all of them, the wind tunnel becomes one of the most efficient tools to improve the athlete performances and to coach as well. Coaching demands a lot of time wind tunnel occupancy, so its operating cost is very relevant. Advantages of specifically developed wind tunnels and possibilities of tests are discussed.

KEY WORDS: aerodynamics, wind tunnel, racing sport, sport ball.

INTRODUCTION: Aerodynamics forces are a function of the square of the speed, so the power goes with the cubic of the speed. In many sport specialities, such as car and motorcycling racing, speed has always been very high, so aerodynamics has always been focussed as a very important aspect of the machines; in this case both, drag and lift of the machines must be taken into consideration. Speed in cycling has reached rather high values to take care of aerodynamic forces, mainly because the available power to move the machine is very limited, some hundred watts, and the energy too. Since twenty or thirty years ago a lot of efforts have been made to reduce the drag in cycling, acting on head protectors, cloths, the bicycle itself, cyclist positions, etc. The earliest reference of using wind tunnel to improve aerodynamics performances of cyclists corresponds to the Renault team in 1979. The technical advisor during such tests was M. Mémaril, who had developed the "egg shape" in skiing. The innovations were not only the new bicycle Profile, but also a new position, that according to Genzling (1984) means more inclined. But there are other man-powered sports where aerodynamic forces are very important as well. Many authors such as Kyle & Caiozzo (1986), Dapena & Feltner (1987) have made calculations to determine the effect of drag reduction on runners´ performance. This proves that the effects are in the limits of records improvements. In other disciplines, such as discus throw (Bartlett, 1992; Hay & Yu, 1995), javelin throw (Bartlett y Best, 1988), all games involving any kind of balls (Davies, 1949; Lyman Briggs, 1959; Rabi Metha, 1985), etc, the aerodynamic forces are important to improve throw distances and abilities. Downhill speed skiing is also a sport where aerodynamic forces are very important, in particular sky jumping is a speciality where even the control of the aerodynamics forces becomes vital for the athlete (Steve Newman). The relative high speeds reached in skating enforce this sport to focus on drag reduction too (van Ingen, 1982). The background related to the interaction between air and bodies is very well presented in Kreighbanm & Barthels (1996). Human body, even riding a bicycle, must be considered as a bluff body, on the other hand, Magnus effect, appearing in balls, javelins and discus rotation, is not a potential effect, so viscous flows must be considered when studying the aerodynamics of athletes and aerodynamic projectiles, as well as for the study of the badminton ball. In these conditions, wind tunnel represents probably the most efficient tool to improve the performances of athletes in all the speed disciplines and to study the behaviour of javelins, balls and discus during flight. The aim of this paper is, first of all, to present the wind tunnel, as a general aerodynamic tool, and afterwards to refer different applications to sport activities.

THE WIND TUNNEL: Since the very beginning of the powered flight, wind tunnel has been one of the most important tools to develop aerodynamics configurations. Figure 1 represents a closed circuit wind tunnel, which has been developed for civil and sport applications by the Instituto Tecnológico y de Energías Renovables (www.iter.es) in Tenerife, Canary Islands. The test section dimensions are 2.0*2.0*3.0 m, the total power is 198 kW, and the maximum operating speed is 57 m/s (200 km/h).

Figure 1. Scheme of a closed circuit wind tunnel



The flow is accelerated from the settling chamber to the test section through the contraction, which allows to get a uniform low turbulent flow in the above mentioned test section, where the element to be tested must be placed and fixed. A variable frequency alternating current feeding system allows the operator to select the wind speed in the test section, any value from 3 m/s up to the maximum. For general purposes, there is an external balance, placed below the test section, where the wind actions on the model or tested item can be measured. In this particular case it is possible to anchor a bicycle training system to be able to measure the wind actions on the cyclist during pedalling.

WIND TUNNEL TESTS: For general purposes, validity and applicability of wind tunnel tests results are based upon similarity laws. According to those laws, non-dimensional results of aerodynamic tests performed on scaled models, at a similar Reynolds number than real conditions or above its critical value, are the same than for the original. In aeronautical applications, the use of scaled models is mandatory because of the current size of the aircraft. In sport applications, the size of the wind tunnel test section can allow to use just human beings as models, keeping the wind tunnel size at a very reasonable value. So, on the one hand side, the wind tunnel can be used just for testing, but, on the other hand, it can be used for coaching as well. As mentioned above, the wind tunnel has been used for testing and design balls, javelins and other sport instrument. Such tests have been very extensive, so they have covered nearly all the possibilities in the area. That is the reason why we are going to pay more attention to those involving simultaneously test and coaching, that being the case of cycling, racing, sky. In these cases at the time when new positions or sport ancillaries are tested, it is possible and convenient to coach the athletes to wear such material and to reach the new positions, even with simulation of specific trials. We do believe that the content of the above presented references are more than enough to justify and show that wind tunnel has pay an important role in record improvements and, of course, it will in the future. In the case of cycling, for instance, once some limitations has been introduced in the bicycle dimensions, reducing the freedom of the aerodynamicists to find the best position, the performances of the cyclists have been reduced 10%, more or less. Nevertheless, we have no doubt that it will only be a matter of time and effort, testing and coaching, to be able to reach as good performances as in the past. In any case, we would like to point out some advantages of wind tunnel tests and coaching, especially focusing cycling. In this sense, safety should be mentioned in the first place, although we are going to show the technical aspects more in detail. Reproducibility of a full variable control is the first advantage in our opinion. Using a computer-controlled bicycle training system, the exact profile of a racing can be reproduced, including wind conditions, as many times as demanded, being able to determine the influence of any change, the evolution of the cyclist, in terms of position improvements and performances. Such control is absolutely impossible in road tests. The paraphernalia involved in wind tunnel tests is more reduced and less expensive than when on-road tests are performed. Wind tunnel tests only involve to the cyclist, the coach, and the technician, apart from the tunnel operator. Neither car drivers, nor safety people are needed, for example. In wind tunnel tests the results can be displayed practically in real time, the aerodynamic drag, the power, wind velocity, simulated slope, etc are known. So the productivity of these tests can be very high, and a shorter time can be requested to achieve targets. The main problem for coaching applications may come from the cost. Wind tunnels for aeronautical applications, which are the majority of those currently existing, have a very high operating cost. Such cost is justified for the aircraft development, but not for sport coaching. Those wind tunnels must have a very good flow quality, for instance, which is not necessary for our purposes. So, a new generation of wind tunnels, with a size and operating speed according to sport applications, with a reasonable flow quality, but attending to low cost operation should be developed to get a massive use of these facilities for sport test and coaching. Fortunately, such tunnels would be compatible with other, called civil applications, therefore the experience of the ITER in the Canary Islands, offering low cost and high productivity tests, may and must be repeated in many other places in the future.

CONCLUSIONS: According to many experiences, wind tunnel tests are very important to improve performances and coaching in a wide range of sports. Nevertheless, current costs of aeronautical tunnels are very high for such purposes. The alternative is on the specifically developed ones of a better economical efficiency.

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