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ScienceDirect

Procedia Engineering 147 (2016) 92 – 97

Procedia Engineering

www.elsevier.com/locate/procedia

11th conference of the International Sports Engineering Association, ISEA 2016

Some results on bobsleigh aerodynamics

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Abstract

Bobsleighs races nowadays are decided upon hundredths of a second. As the margins are that small the aerodynamics of a bobsleigh can play a significant role in a race outcome. This paper investigates the influence of the gap between the nose and the rear cowling of a two-man bobsleigh. The paper especially focusses on the misalignment between both cowling parts due to lateral rotation in a track bend. CFD analyses and wind tunnel tests have shown that the rotation of the nose increases the drag due to an enlarged frontal area and due to adverse effects of the airstream flowing into the cavity. The results are used to define an area of investigation to alter the gap geometry which may lead to reduced drag when the bobsleigh parts are misaligned.

Peer-review under responsibility of the organizing committee of ISEA 2016

Keywords: Bobsleigh, cowling misalignment, aerodynamics, CFD, wind tunnel tests

1. Introduction

For a long time sleighs have been used as a means of transportation. After the addition of a steering mechanism to the steel frame in the late 19th century, the sport of bobsleighing was born. In this sport, also known as the Formula 1 of the Winter Games, speeds of over $150 km/hr$ are reached in races where the winner leads the pack by only hundredths of a second [1]. In order to create an advantage over the competitors slight geometrical changes to a bobsleigh can increase the performance.

The design of modern bobsleighs is strictly regulated by the rules imposed by the International Bobsleigh & Skeleton Federation (IBSF) [2]. These rules are mainly imposed to guarantee the safety of the athletes but they also reduce the possibility of an unfair competition as larger teams have more resources to design and improve the bobsleigh. However, there is some freedom left in the design in order to gain marginal advantages over the competitors, as suggested by Dabnichki [3]. However, most of the research performed investigates the bobsleigh as a single body where in real-life the cowling consist of two parts connected by means of a pivot axis. During a race both parts are misaligned most of the time due to the track configuration. When the front and rear cowling are misaligned the frontal area is increased and the gap between both parts is increased both resulting in an increase in aerodynamic drag. This paper describes an investigation into the effect of the misalignment between front and rear cowling on the aerodynamic drag of a two-man bobsleigh. The results are being used to define a project in which the influence of the gap configuration on the aerodynamic drag will be assessed.

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1877-7058
Peer-review under responsibility of the organizing committee of ISEA 2016
doi:10.1016/j.proeng.2016.06.195

2. The sport of bobsleighing

In 1924, a year after the IBSF was founded, the sport of bobsleighing took its first appearance in the Winter Olympics in Chamonix, France [4]. When the stakes of winning became higher, strong and large athletes were deployed for the competition. After the inclusion of a weight limit, to avoid this game changing case, the sport as it is known today was born. Research has been performed to increase the performance and speeds of the sleighs by improving the geometry and materials, understanding the forces acting on the bobsleigh and improving the aerodynamic characteristics of the bobsleigh.

2.1. The bobsleigh

The first and most important design feature of the bobsleigh is that it provides safety to the athletes. In order to satisfy this requirement a set of strict regulations is imposed by the IBSF on the geometry of a bobsleigh [2]. These regulations describe the exact shape of a bobsleigh with marginal room for modifications.

The most characteristic aspect of a bobsleigh is the two-part configuration where the frame is connected pivotally. The nose of the bobsleigh is able to rotate with respect to the aft body which ensure more gradual and faster cornering during a race. The entire body is required to have a convex shape containing front and rear bumpers to provide a safety buffer in the case contact is made with the track walls. These bumpers are usually integrated in the cowling design in order to reduce unfavourable aerodynamic interactions in the junctions.

In order to minimise a gravitational advantage during a race a weight limit is imposed on the bobsleigh. During the race the only force which is able to accelerate the bobsleigh is the gravitational force due to the combined weight of the sleigh and its crew. A two-man bobsleigh must weigh at least $170kg$ excluding the crew. A maximum weight of $340kg$ or $390kg$ is imposed on the bobsleigh including the athletes and other equipment for women and men respectively in the two-man discipline.

2.2. Forces acting on a bobsleigh

A bobsleigh race comprises a downhill course of about 1200-1650m length which can be divided into three phases: the start, the drive phase and the finish [2,5]. At the start phase the athletes push-off, increase the speed and get into the sleigh. After this 'loading' the gravitational force is the only accelerating force acting on the bobsleigh while the ice friction and aerodynamic drag forces oppose this acceleration. Next to the pilot skills the geometry of the bobsleigh is therefore of utmost importance to enable good race performance. During this drive phase the bobsleigh will encounter a collection of elements with varying difficulty. At the finish the final time is set and the sleigh must be decelerated by an uphill stretch and a brake.

Two cases of forces acting on the bobsleigh can be identified along a track. The case where the bobsleigh travels a straight line and the case where the bobsleigh encounters a turn. In a straight line the bobsleigh can be seen as a symmetrical body where forces only act in the longitudinal direction. In order to increase the performance the weight must be maximised while the ice friction and aerodynamic drag have to be minimised. When the bobsleigh travels through a turn in the track the bobsleigh encounters a centrifugal force pushing the sleigh outwards and the pilot needs to steer the bobsleigh in order to hold the best line. This steering, where the runners are rotated to create a moment over the bobsleigh, exerts an extra resistive force that slows down the bobsleigh [3].

2.3. Aerodynamics

The best bobsleigh performance is achieved when the resistive forces, as discussed before, are minimised. A large part of this resistive force is caused by the aerodynamic drag of the bobsleigh. This drag force consists of two main sources: the skin friction and the pressure drag force [6,7]. The drag on bluff bodies, non-streamlined bodies as bobsleighs, is dominated by the shape of the geometry and influenced by flow separation, hence the pressure drag is the largest drag component [6–8].

When a moving bobsleigh is investigated it can be seen that a pressure difference is present between the flow in front of the body and the flow trailing the sleigh, caused by flow separation [8,9]. At regions of high curvature and sudden geometrical changes - such as the gap between the cowling parts, pilot helmet and the rear end of the bobsleigh