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Original Research Article

Exposure of the human eye to wind

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ARTICLE INFO

Article history:
Received 23 January 2015
Received in revised form
22 May 2015
Accepted 13 July 2015
Available online 8 August 2015

Keywords:
Human eye
Protective material
Numerical analysis
Computational fluid dynamics
Contact lens

ABSTRACT

We report an investigation of the exposure of the human eye to wind. The study was carried out at wind speeds of 40, 80, and 160 km/h. The pressure and forces acting on the eye were examined using the ANSYS CFX software package. The results highlight the necessity of using glasses, contact lens, or protective equipment when, for example, riding a motorcycle, skiing, parachuting, and paragliding.

1. Introduction

The human body may be exposed to wind while, for example, walking, driving, cycling, or riding a motorcycle. The eye is one of the most important organs that may be exposed to wind. Therefore, the use of equipment such as glasses is recommended when, for example, riding a motorcycle to avoid the potentially harmful effects of wind. Many studies related to the human eye have been carried out. Some of these have been related to the external portion of the eye, and others to the interior of the eye. Abouali et al. [1] reported a numerical simulation of the fluid dynamics in the vitreous cavity due to saccadic eye movement. Crowder and Ervin [2] investigated the fluid pressure in the human eye using numerical simulations. Ferreira et al. [3] reported a numerical simulation of aqueous humor flow for healthy eyes, in which they described variations of the pressure and velocity in the interior of the eye following drug use. Wessapan et al. [4] investigated the influence of the ambient temperature on the heat transfer in the human eye during exposure to electromagnetic fields at 900 MHz; the insert acronym definition (SAR) and temperature distribution at the front of the eye were studied for electromagnetic radiation power densities of $q = 10$, 50, and 100 W/cm^2. Villamarin et al. [5] reported a three-dimensional (3D) simulation of the aqueous flow in the human eye, and Ooi et al. [6] investigated bioheat transfer in the human eye. Studies [1–6] focused on the human eye; however, there have also been studies of animal eyes, in particular, those of cats [7–11]. Kavousanakis et al. [12] investigated changes in the pressure and velocity in the eye over time steps of 8 h, 1 week, 4 weeks, and 8 weeks. In the first stage, drugs were applied

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http://dx.doi.org/10.1016/j.bbe.2015.07.001

Nomenclature

A_{prj}	projection area (m^2)
C_D	drag coefficient
c_p	specific heat (J/kg K)
D	diameter of the human eye (mm)
D_{es}	external diameter of the eye socket (mm)
F_x	force in the x direction [N]
g	acceleration due to gravity (m/s^2)
k	thermal conductivity (W/m K)
L_y	number of points on the pupil curvature in the vertical direction
q	heat flux (W/m^2)
Re	Reynolds number ($u_\infty D/\upsilon$)
T_∞	air temperature (°C)
t	time (s)
u, v, w	velocity in the x, y, and z direction (m/s)
u_∞, $u_{average}$	average fluid velocity (m/s)
α	thermal diffusion (m^2/s)
μ	dynamic viscosity (Ns/m^2)
υ	kinematic viscosity (m^2/s)
ρ	density (kg/m^3)

to the eye; then the effects of the drug on different portions of the eye were investigated. Pascolo et al. [13] reported a study into extreme rotation of the eye in different directions. Gasmelseed and Yunus [14] reported a 3D numerical model of the human eye, and investigated the effects of electromagnetic fields on the eye tissues. Similar other studies have also been reported in this area [15–20].

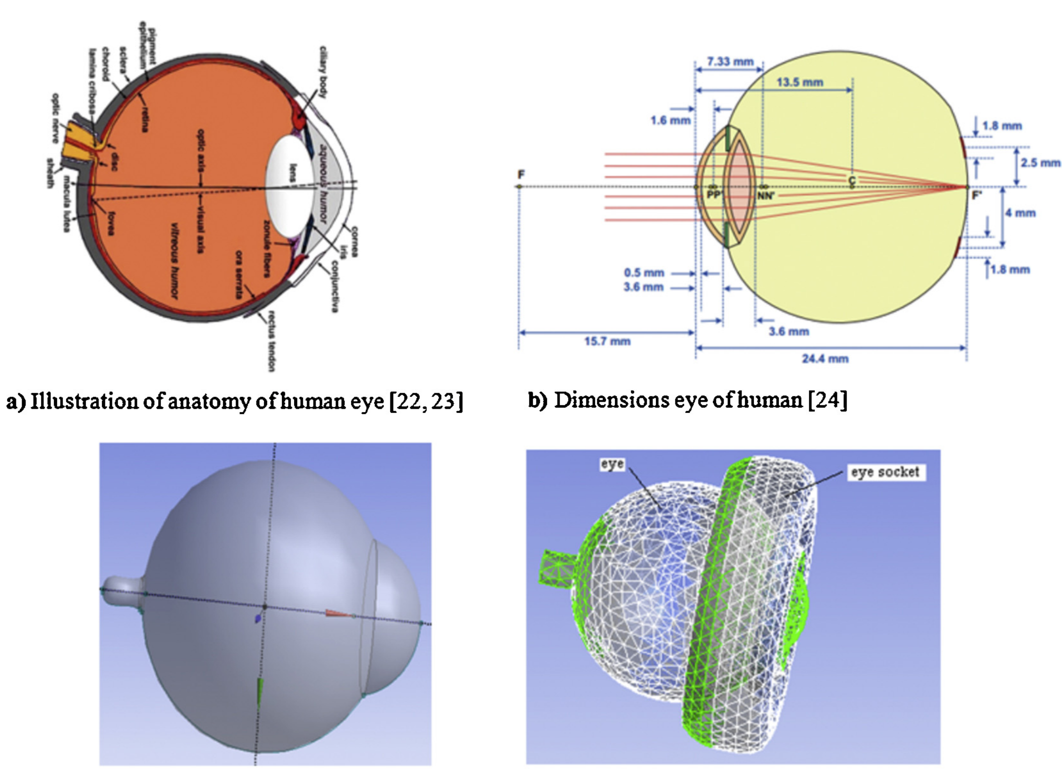
Here, we investigate the effects of wind on the front of the eye at air velocities of 40, 80, and 160 km/h. In the first stage, the simulated eye was exposed to the wind directly. In the second stage, we investigated methods of reducing the wind effects using protective equipment such as glasses. We found that an obstacle placed in front of the eye reduced the wind effects.

2. Modeling the human eye

The dimensions of the human eye were used in the model. Simulations were carried out using the software package ANSYS CFX [21]. A hybrid mesh structure was used, as shown in Fig. 1. The convergence criteria were 1×10^{-6} for the continuity and energy equations. Expressions for u, v, and w were used as part of the solution process, and we assumed laminar flow conditions. The maximum number of iterations was 1000; however, we found that convergence occurred after approximately 250 iterations. The dimensions of the model were determined by considering an adult human eye, as shown in Fig. 1b [22–24]. Air at 25 °C was used as the fluid; the thermophysical properties of air are listed in Table 1.

2.1. *Mesh accuracy and comparison with literature*

A suitable number of elements are required for the simulations to provide a trade-off between the time required for the calculation and the accuracy of the results. Table 2 lists the results obtained with different numbers of elements and



a) Illustration of anatomy of human eye [22, 23]

b) Dimensions eye of human [24]

c) Modeling of human eye

d) Meshing of human eye

Fig. 1 – Dimensions of the human eye, as well as the simulation model and mesh [22–24].