GOLF BALL AERODYNAMICS

A dissertation submitted to the University of Manchester
for the degree of Master of Science
in the Faculty of Engineering and Physical Sciences

2014

James Fielder
School of Mathematics

Contents

Word count xxxxx

List of Tables

List of Figures

Abstract

In this project we work on golf balls and stuff.

Declaration

No portion of the work referred to in the dissertation has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Intellectual Property Statement

i. The author of this dissertation (including any appendices and/or schedules to this dissertation) owns certain copyright or related rights in it (the "Copyright") and s/he has given The University of Manchester certain rights to use such Copyright, including for administrative purposes.

ii. Copies of this dissertation, either in full or in extracts and whether in hard or electronic copy, may be made **only** in accordance with the Copyright, Designs and Patents Act 1988 (as amended) and regulations issued under it or, where appropriate, in accordance with licensing agreements which the University has entered into. This page must form part of any such copies made.

iii. The ownership of certain Copyright, patents, designs, trade marks and other intellectual property (the "Intellectual Property") and any reproductions of copyright works in the dissertation, for example graphs and tables ("Reproductions"), which may be described in this dissertation, may not be owned by the author and may be owned by third parties. Such Intellectual Property and Reproductions cannot and must not be made available for use without the prior written permission of the owner(s) of the relevant Intellectual Property and/or Reproductions.

iv. Further information on the conditions under which disclosure, publication and commercialisation of this dissertation, the Copyright and any Intellectual Property and/or Reproductions described in it may take place is available in the University IP Policy (see http://documents.manchester.ac.uk/DocuInfo.aspx?DocID=487), in any relevant Dissertation restriction declarations deposited in the University Library, The University Library's regulations (see http://www.manchester.ac.uk/library/aboutus/regulations) and in The University's Guidance on Presentation of Dissertations.

Acknowledgements

I would like to thank my supervisor Prof. Jitesh Gajjar for his guidance during the project without which I would have been completely lost. Additionally, I would like to thank the Royal and Ancient Golf Club for their sponsorship of the project and Dr Steve Otto for his guidance and assistance.

Chapter 1

Introduction

Stuff here about the project and aims and such.

1.1 A brief history of golf

The origins of the game of golf are difficult to trace, with suggestions that the game originated in either Scotland, France, the Netherlands, China, or even going back as far as the Roman Empire. Golf in its more modern incarnation however, is agreed to have originated in 15th century Scotland, where the first written records of the game are (somewhat humorously) related to King James II of Scotland banning the game in 1457 for fear of a decrease in archery practice in its favour.

From the 18th century onwards golf began to take form fully in Scotland, with the founding of both The Royal and Ancient Golf Club in St Andrews and The Royal Burgess Golfing Society in Edinburgh. The oldest surviving rules of golf also date from this time and these rules have been in a state of constant revision up to the modern day.

In the 19th century the popularity of golf vastly increased, seeing larger numbers of people knowing and playing the game, and the start of the first major tournaments. Additionally, the game spread out to encompass much of the British empire, to the United States and eventually to Japan, making golf into a global sport supported by a plethora of associated manufacturers, sponsors and organisations.

In the modern day, golf is potentially one of the largest sports on earth, with golf tournaments, golf manufacturing and related industries accounting for hundreds of

billions of pounds of economic activity. If successful on the golf tournament circuit, golf professionals can earn huge sums in prize money. With the players themselves and their sponsors having such a vested interest in success having a consistent and fair rule set is of paramount importance and this is dealt with jointly by The R&A (The Royal and Ancient) in most of the world and the USGA (United States Golf Association) in the Americas.

1.2 A slightly larger history of the golf ball

Golf ball technology has advanced greatly since the advent of the game. Initially, hard wooden balls were used for playing, however these were soon replaced with featherie balls which are leather pouches stuffed with feathers and then painted white.

The next major innovation in the design of golf balls came in 1848, when the gutta-percha ball was invented. This is the first ball to use a rubbery substance as continues to this day, and was easier to make into a proper sphere, unlike the previous types of ball. It was around this time that it was discovered that abrasions to the surface of the ball would improve the aerodynamic properties of the ball, making it easier to control the flight of the ball and increasing the distance at which the game could be played. This would start a series of innovations that would lead to todays dimpled balls, which we will discuss later.

After this the golf ball once again changed form with the advent of using wrapped rubber thread to help the ball to bounce better. This was coupled with the first usage of a plastic covering, in order to protect the rubber inside the ball on impact with the club. This cover also persists to this day, although the inside of the ball has seen significant development.

The modern golf ball has changed significantly from old designs. The interior of the ball is now usually a 3 piece rubber composite, with different properties in each rubber to maximize the controllability of the ball during play. The exterior is a polyurethane cover (normally white but some are in other colours) with usually between 300 to 400 dimples (though these can go as low as 200 dimples, and beyond 600 in some cases). The properties of the ball are stipulated to be within certain ranges, as set by The

(a) "Featherie" balls

(b) Pro V1 ball

Figure 1.1: In 1.1a are "Featherie" golf balls, taken from https://en.wikipedia.org/wiki/File:Featherie_golf_ball.JPG, and in 1.1b is a modern style ball, namely the Titleist Pro V1 ball.

R&A and USGA in the rules of golf. The weight of a ball must not be greater than 45.93g, the diameter no less than 42.67mm and the ball must be spherically symmetric.

1.3 Aims of the project

The aim of this project is to obtain a model for how golf balls fly based on simple physical principles. Given this model we then wish to categorise individual balls based on measurements of their flight, and use this categorisation to predict trajectories for the ball

Chapter 2

Preliminary results

There are some useful results we need which we'll probably write about here Robinson and Robinson (2013)

Bibliography

G. Robinson and I. Robinson. The motion of an arbitrarily rotating spherical projectile and its application to ball games. *Physica Scripta*, 88(1):018101, July 2013. ISSN 0031-8949. doi: 10.1088/0031-8949/88/01/018101. URL http://iopscience.iop.org/1402-4896/88/1/018101.