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Player Fitting of Golf Equipment Using a Calibration Club

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Abstract. As launch and flight monitors become more prevalent in retail and research locations the need for fitting golf equipment has increased. In this paper, the fitting of golf clubs is discussed using a calibration club from which performance of other clubs is predicted. In order to do this, extensive testing, both robot and player, was completed building a database of club responses as a function of ball speed, backspin, and launch angle. From the trajectory data the best fit club for a player was determined. For drivers, the fitting simply consists of maximizing the length of the ball's flight and roll.

1 Introduction

In the early 1990s, golf equipment was going through a renaissance with material advances, increased original equipment manufacturers (OEM) research, and development efforts. Much of the R\&D was focused on the equipment itself with the thinking that better equipment benefits all golfers. Before metals arrived on the scene, there was scientific study of equipment fitting, although it may have not been recognized as fitting. After working on the perfect model of the golf swing, Cochran and Stobbs (1968) explored the possibilities for design of equipment. Even though it was contrary to their search, the research team found individual golfers exhibit patterns characteristic of themselves and different from those of players having very similar swings. Back when metals were making the transition from steel to titanium, there was a beginning of fitting. Pelz (1990) conducted testing on different shafts hit by U.S. PGA Tour professionals and was able to conclude what shafts were better for short, medium, and long hitters.

Currently, there are so many outstanding golf club products it is worthwhile to pick and choose amongst these to match a golfer to a club and/or ball. Making the best choice and customizing the choice has been limited to the big OEMs until recently. Before the early 2000s, the only launch monitors were in companies like Acushnet (Gobush, Pelletier and Days, 1994). These were research devices utilizing photgrammetry made for the development of product rather than fitting the right equipment for a specific player. Without launch monitors, non-OEM research on fitting required testing by taking the distance a ball traveled. For instance, high handicap golfers benefit in 3-wood and 5-iron distance when using 2-piece balls over other types of balls (Hale, Bunyan and Sewell 1994). However, it was somewhat of an arduous task to come to this conclusion. Winfield (1999) took advantage of Acushnet's in-house launch monitor \cite{launch:gobush94} to conduct real ball and club fitting that measured launch conditions and computed flight based on trajectory models (Aoyama 1990, Smits and Smith 1994).

Because only a few companies had the ability to rapidly evaluate a golf shot's launch conditions, fitting of golf equipment was restricted to R\&D departments. But starting in 2002 commercial launch monitors became available commercially launching a golf equipment fitting frenzy.

2 Launch Monitors

The reason golf club fitting is becoming widespread in recent years is due to affordable, commercial launch monitors. These instruments utilize photogrammetry and Doppler radar and range in price from several hundred to tens of thousands of US dollars. Economies of scale and competition are reducing the price allowing for wider availability at point-of-sale, professional fitters, and professionals.

With the exception of the radar unit, initial conditions are captured: ball speed, launch angle, and backspin. Radar based instruments allow for trajectory measurement (velocity as a function of time) as well as spin. While initial conditions suffice for most fitting, it is preferable to have data from the entire trajectory.

As discussed in Winfield 1999, if one knows the launch conditions along with the lift and drag coefficients as a function of Reynolds number and spin ratio a reasonable path may be computed. Most launch monitors operate in this fashion: measure the initial conditions and calculate the path.

3 Optimum Launch

By taking an aerodynamic model for a ball (Smits and Smith 1994), it is easy to compute the carry distance for a variety of launch conditions. The carry distance computed was used as the objective function in an optimization algorithm to determine what backspin and launch angle a player should have for a given initial ball velocity. A simplex method for minimizing the carry distance as a function of backspin and launch angle converged quickly (<1,000 iterations) determining the Smits and Smith (1994) ball optimum launch (Fig. 1).

4 Driver Fitting

Driver fitting has the most obvious objective function for fitting: maximize distance. The choice that most all consumers make is to hit the ball further. Some high level

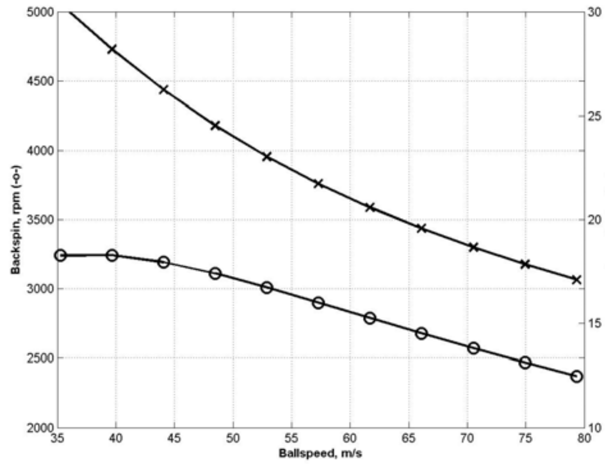

Fig. 1. Optimized launch Conditions for carry and distance over a range of ball velocities.

players will forfeit distance for a specific flight characteristic such as a lower flight. Fitting a player to the best driver may involve trying many products to obtain the best distance. Without a math based fitting algorithm the process may be a random "walk" through products hoping to find the right one before the customer fatigues.

Thus, the need for calibration club fitting which reduces the number of products tried. In this method, a player hits a calibration club and the launch conditions are measured with a launch monitor. Key to fitting with the calibration club method is having tested a broad variety of clubs for comparison. A database of many driver's launch conditions, tested on a robot, have been hit and analyzed. Included in the database are the launch conditions of the calibration driver. Each club model and loft has been tested over a wide range of club head speeds allowing the fitting of most all players. Based on the relative performance of the drivers searched in the database, a driver can be recommended to the customer.

Each driver model in the database was tested at nominal club head speeds of 35.7, 40.2, 44.7, 49.2, and 54.7 m/s. Ball speed was used as the independent variable since the launch monitor records ball speed. At all club head speeds the appropriate shaft was used for testing. Some club speeds may have more than one shaft flex to be tested. In general, two similar model driver heads tested at the same speed with different flex shafts produced similar launch conditions for transition club speeds. Figure 2 shows backspin data for a single club head model, multiple lofts, tested on a robot as a function of ball velocity. Ball speeds with double data points are the transition speeds, and the two data points represent a shot with two different shaft flexes. It is seen that the data for a given loft head blends well into a single data set.

Figure 2 show the backspin for a single model, 400 cc, driver over a range of club head speeds and club head lofts. In spite of the scatter of the data points, it is easy to see from linear fits to each loft that this driver creates a set of characteristic launch conditions. Linear regressions of the data as a function of velocity generate well defined characteristic lines offset as the loft changes. Note that the 8.5 degree loft driver data looks different indicating that it should be re-tested. There was most likely a setup problem in testing that particular driver.

Having characteristic curves like this is the starting point for the fitting. When a player hits these drivers the spin and launch conditions may not match the absolute numbers shown, but the relative differences remain in tact. It is assumed that the data shown in Fig. 2 for robot testing will remain linear and simply shift the club model's ordinate values. The player's launch conditions can be scaled onto the database or the database parameters can be scaled to the player.

Figure 3 shows player data superposed on the linear fits for the model considered. The error bars for the players shots indicate a standard deviation span. For each driver, 5 to 8 shots were recorded. If more shots were taken it is anticipated that the standard deviation would be significantly reduced. In addition, backspin is one of the most difficult launch parameters to measure with accuracy. It is seen that backspin from the drivers hit by the player reasonably match that of the robot. Some of the differences between spins is not quite the same as that of the robot, however, Table 1 shows what may cause this difference. For the robot data, several clubs were hit and averaged into a single line. The different clubs all had the same manufacturers loft, but individually the lofts vary. On average, the nominal lofts are slightly different than the published lofts due to manufacturing variation. However, when a player grabs a single club it can be different from the nominal. In Fig. 3 it appears that the best loft is between the 8.5 and 9.5 degree heads, however, the heads tested were 9.0 and 10.5 degrees even though they were labeled as 8.5 and 9.5 degree products. Thus, the player should most likely play with a 9.5 degree driver in this model.

Table 1. Driver properties for lofts tested.

Published Loft, deg	Nominal Loft, deg	Measured Loft, deg	CG Height mm	CG Depth mm	CG MOI g-cm^2
7.5	8	8.5	23.8	17.6	4030
8.5	9	9	22.8	16.3	4030
9.5	10	10.5	23.7	16.1	4101
10.5	11	11	23.5	17.2	4101
11.5	12	12	23.6	16.1	3960

Once the database parameters have been scaled for player hitting the calibration club, predicted launch conditions for each club in the database were computed. From this the database clubs were sorted to determine the best performing clubs for the player. Two sorting methods have been used to do this based on initial backspin or carry distance based on a trajectory code. If the aerodynamics parameters of the ball are well known, the latter method is preferred. However, for wide scale fitting the ball used may vary. In this case the initial spin criterion works well.

Figure 4 shows a ranked comparison of 40 different loft and brand drivers compared to the 9.5 degree driver hit by the player (65.3 m/s ball speed, 2800 rpm backspin, 14 degree launch angle). There are 23 drivers that will give the player a slight improvement in distance over the calibration club. Low ranking drivers are those imparting too much spin on the ball. The distance for each driver was calculated using a simple trajectory code (Smits and Smith 1994) along with the USGA's ITR roll model.

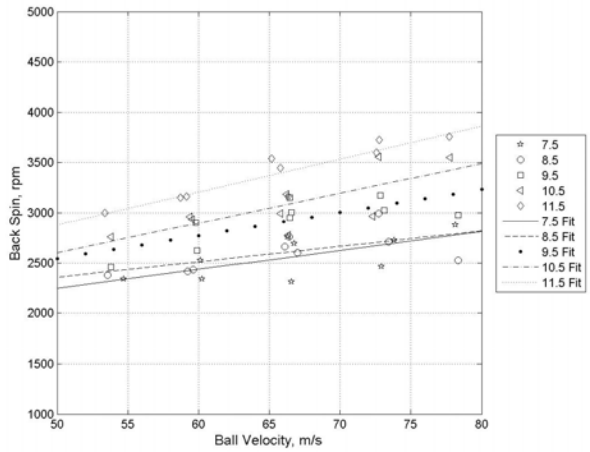

Fig. 2. Single model driver backspin as a function of ball velocity and loft.

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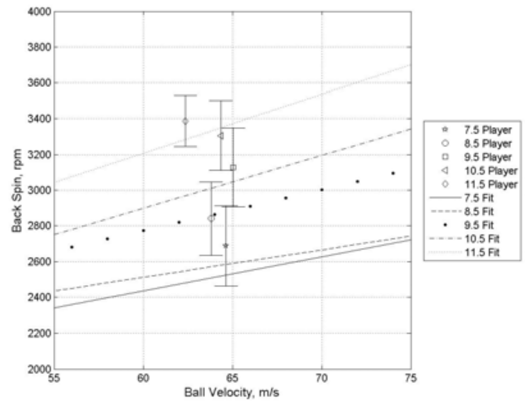

Fig. 3. Player test data superposed on driver spin lines.

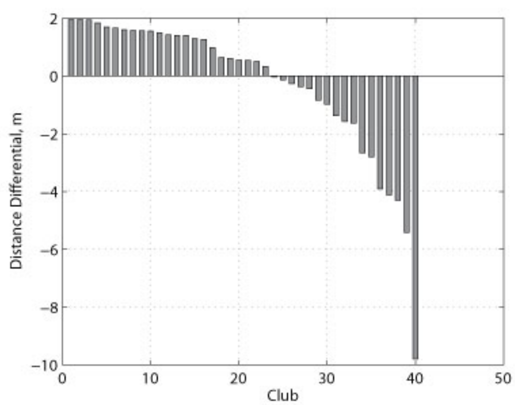

Fig. 4. Comparison of 40 driver models referred to a single 9.5 degree calibration driver.

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