proceedings

ISEA 2018
Brisbane Queensland Australia
26-29 March 2018
'Engineering of Sport'

MDPI

Proceedings

A Novel Putter Design to Minimise Range Variability in Golf Putts †

Nicholas J. Emerson [1], Tom Morris [2] and Jonathan R. Potts [3,*]

1 School of Engineering and Built Environment, Griffith University, Gold Coast Campus, Queensland 4222, Australia; n.emerson@griffith.edu.au
2 Ping Europe Limited, Corringham Road, Gainsborough, Lincolnshire DN21 1XZ, UK; tommo@pingeurope.co.uk
3 Faculty of Arts, Computing, Engineering & Sciences—Sheffield Hallam University, Sheffield S1 1WB, UK
* Correspondence: j.r.potts@shu.ac.uk; Tel.: +44-0-114-225-6450
† Presented at the 12th Conference of the International Sports Engineering Association, Brisbane, Queensland, Australia, 26–29 March 2018.

Published: 6 March 2018

Abstract: Putting accounts for more shots in a round of golf than any other type of play. The percentage of putts holed decreases as putt length increases, because golfers struggle to achieve a consistent range and direction. Range variation has been partly attributed to the ball striking the club face away from the central plane of the putter face. Tests have shown a 30 mm off-centre impact can reduce the roll distance of a putt by 13%. In this paper, changes in mass distribution of the putter body and the addition of a flexible striking surface are considered. Physical testing and Finite Element Analysis are used to produce a club design with more consistent roll distance. Redistribution of mass reduced the roll distance variation across the clubface. Combining this with a flexible impact surface reduced the variation between a central impact and one 20 mm from center to just 1%. The proposed design could significantly reduce distance variation; aiding golfers in holing putts. Future work will optimise the design and validate through physical prototyping.

Keywords: sports; FEA; golf; testing; equipment; COR

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1. Introduction

Athletes of all abilities have variation when attempting to strike an object consistently. This leads to variability in the direction and the distance that the object travels. In golf, putting typically accounts for around 43% of a round's strokes [1,2]. Arguably therefore, success in putting is the largest contributor to overall success in golf. Research shows that even Elite players (<5 Handicap) can have an average of 16.9% variability in putting distance from one shot to the next. As the distance to the hole increases, the chances of 'making' the putt diminish. Competition data shows that professional players will succeed in holing a shorter (0.91 m) putt 96% of the time, quickly falling to 45.5% for longer (1.52 m) putts [3]. In longer putts the percentage in range variability has a greater absolute effect, often leading to further long putts.

It has been shown that average distance variability from highly skilled players is in the order of ±10.6% of total putt length. This stems from misreading of the green, distance variation in the playing surface, and from variation in technique. Karlson et al. propose that green reading has the highest relative importance (60%) followed by technique (34%) and then playing surface (6%) [4]. Testing has shown that impacts that are slightly out of line with the central plane (±10 mm) have little impact on putt distance (approx. 2% variation) [4,5]. However; this range increases rapidly as the ball is struck further from the center of the club face, as it might be by less skilled players (a loss of up to 12% of total roll distance) [4].

There are marketed examples of putters designed to minimise distance variation. Many manufacturers have considered the redistribution of clubhead mass. Lindsay [6] states that maximising moment of inertia is now almost a universal design aim for putters. By contrast, fewer manufacturers have considered the club's 'face' as a means to control outbound ball velocity. Some have considered varying the texture of the impact surface, adding grooves to reduce the surface area in contact with the ball during impacts. Muller et al. [7] demonstrated that the size of the contacting surface can affect the dwell time of impacts, resulting in a lower outbound ball speed.

The aim of the present work is to consider mass distribution of the putter body and a re-design of the putter face. This intention being to produce a design with more consistent outbound ball velocity for all impact locations, and therefore a putter that acheives more consistent roll distance.

2. Materials and Methods

The putter head was broken down into two parts, the 'body' and the 'face', and these were tested separately. The first test considered the face of the putter, which was designed to be mounted at the outside of the putter and suspended in front of the main body as shown in Figure 1. Faces of varying thickness were tested to determine their effect on outbound ball speed. It should be noted that the Royal and Ancient (R&A) [8] have a ruling excluding clubs with a 'spring effect', but this focusses on increasing shot distance and is considered effective for all clubs *except* putters.

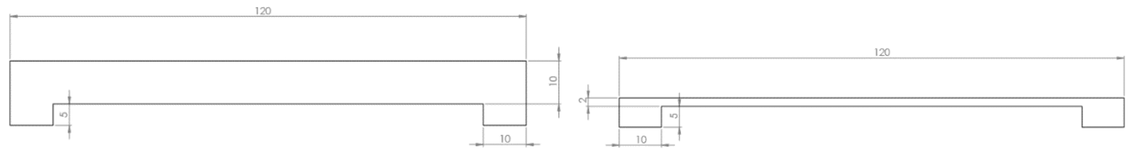

Figure 1. Flexible face major dimensions. The faces ranges from 10 to 2 mm thick in 2 mm intervals.

The effective coefficient of restitution of each face was determined via drop test. Each face was impacted in three locations, with ten trials at each location. Titleist Pro-V1TM [9] balls were dropped from 1 m, without spin in accordance with previous tests [7,10]. Rebound height was determined by digitising images from a Phantom MIRO Ex4-4096MC series high speed camera. Effective COR (e) was calculated from the ratio of rebound (h) to drop height (H):

$$e = \sqrt{\frac{h}{H}} \quad (1)$$

The second test considered changes in the distribution of mass of the body as a method to reduce club rotation at impact. The re-design was constrained by Appendix II (Design of Clubs) 4b(iii) of the R&A Rules [8] which provides regulations on the acceptable dimensions of putters.

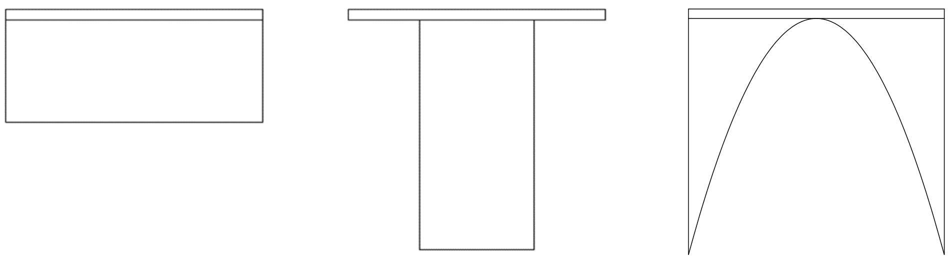

Figure 2. Three golf putter head configurations all with identical 5 mm face, body mass evenly distributed (**left**), located centrally (**middle**) & peripherally (**right**).

The analysis considered three configurations of putter body, with reference to Figure 2. The first had mass located centrally around the mid plane. The second incorporated a 'blade' style design with the mass distributed evenly across the putter. The final design utilised a non-uniform distribution of mass, with more material at the periphery. The peripherally-weighted design used a function derived from the predicted deflection of a beam built in at both ends. The depth of the putters were controlled such that each weighed 350 grams.

Finite Element Analysis was undertaken to examine the effect that changing the putter body had on outbound ball speed. The simulation used the Explicit Dynamics functionality of Ansys 17.1, in line with previous published works [11]. The ball was modelled as a two-piece bonded structure, with a core and outer layer, whilst the putter body was solid aluminium (Table 1). The three body configurations were impacted from the central plane to 30 mm from the centre at 10 mm intervals. The inbound and outbound velocities of ball and club were extracted to determine the effective Coefficient of Restitution (COR) of each design, which is proportional to rolling distance.

Table 1. Material properties inputted for the simulation procedure.

Component	Putter Face	Ball Outer Layer	Ball Core Layer
Material	Aluminium (6082-T6)	Polyurethane	Polybutadiene (Mooney-Rivlin Model)
Elastic Modulus, E (GPa)	70	221	70
Poisson's Ratio	0.33	0.46	0.46
Specific Gravity (g/cm^3)	2207	878	1204

3. Results

Results from the drop tests (Figure 3) demonstrated that a flexible face has an effect on effective COR. The 4 mm face showed the most promising trend, with a gradual increase in effective COR until the 20 mm impact position, before a slight decline. The 2 mm plate showed the greatest increase when compared to the central location. However, the 2 mm trend differs from the other faces on test, showing comparatively large fluctuations in effective COR.

The effective COR of each mass distribution was determined from simulation. This was normalised against the value for a central impact and is plotted in Figure 4. It is immediately apparent that the putter with the largest Moment of Inertia, namely the perimeter weighted putter, provided the least variation in roll distance. The traditional bladed putter showed much greater variation, which is commensurate with results obtained by Karlsen et al. who also show that high MOI clubs can reduce range variability [4].

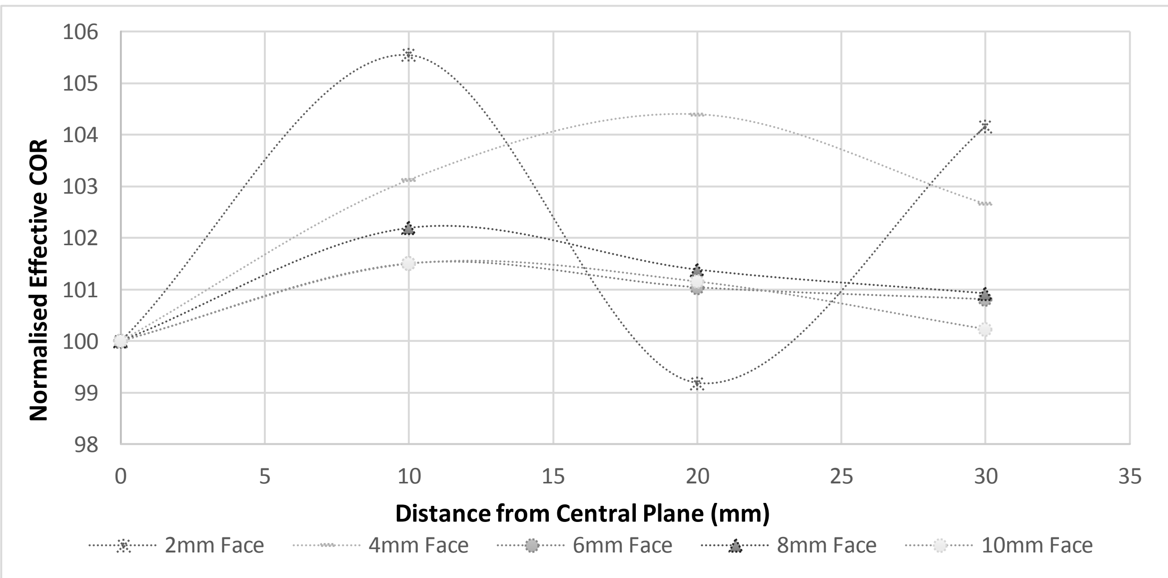

Figure 3. Variation in effective COR across the putter face, for each of the face thicknesses tested.

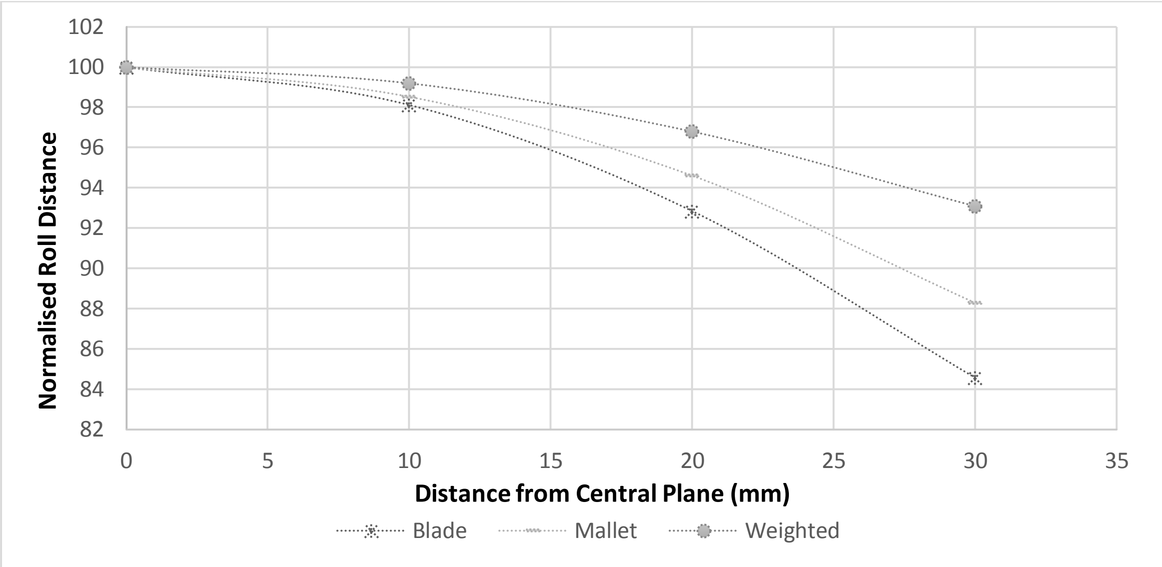

Figure 4. Normalised roll distance for each of the body designs.

The two test outcomes were then combined to consider their collective effect. The projected roll distance was calculated and normalised against the central impact in order to consider the effects of club changes in minimising across-face distance variation. The combined results show that the 4 mm face, with a perimeter weighted body, has reduced variation in roll distance between central and 20 mm off-centre positions, to as little as 0.9%, as shown in Figure 5. For comparison, a standard bladed putter with a fixed face was found to exhibit a distance variation of 7.2% across the same impact position range. Whilst variation does increase from 20 to 30 mm, the 4 mm and peripherally weighted combination produce near identical results to the periphally weighted-only putter at 30 mm.

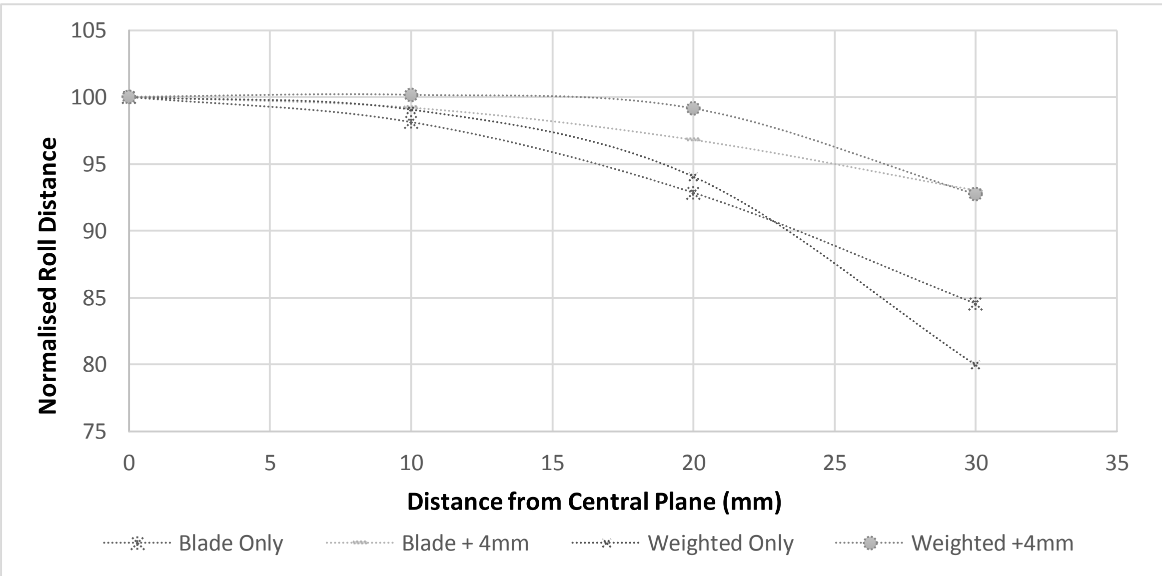

Figure 5. Selected configurations for comparison. In all combinations the flexible face improves roll distance consistency until at least 20 mm from the central plane.

4. Discussion

It is apparent that combining a more flexible putter face with a revised mass distribution could be an effective methodology in reducing variability in roll distance when putting. From the results obtained thus far, the 4 mm putter face and perimeter weighted body design provides the most effective solution. This combination achieves excellent consisitency and reduces range variation to less than 1% at 20 mm from the central plane.

An interesting finding is the variability in effective COR for the flexible faces. Both the 4 mm and 2 mm faces demonstrate trend reversals at some point along the face, with the 2 mm face showing a relative increase in effective COR for a moderate offset (10 mm), thus increasing the potential roll distance. This is undesirable in terms of putter consistency, yet warrants further investigation as the design moves forward. These could be inverse changes in local COR due to excitation, and vibrational analysis will be considered. Additional putter face thicknesses will also be considered in further work, as will the effect of non-uniform thickness distribution across the face.

The study represents early findings in the design of a new putter. Accordingly, there are limitations which will be addressed as the work continues. The results presented here limit the number of impact locations considered to 10 mm intervals, replicating the methodology of Karlsen et al. [4]. The limited data points make the change in COR somewhat difficult to describe. Whilst the use of a two-piece ball has been implemented effectively, and is replicated in literature, Hayase et al. propose as many as 6 layers of material are required to accurately simulate a golf ball [12]. Further resolution will be sought in future FEA work.

It should also be noted that the results are the combination of two studies and are therefore somewhat extrapolated in nature i.e., there is no combined prototyping at this stage. An obvious next step from the presented work is to construct the entire arrangement and undertake physical testing using a pendulum putting rig, for consistency. Following this, physical testing with participants would be implemented to observe the actual effect of the various proposed designs whilst in use, in combination with practical variability in impact location for players of varying ability.

5. Conclusions

Tests were undertaken to consider the effects of changes to putter mass distribution and the rigidity of the striking surface. The aim was to produce a putter with minimal variation in ball roll distance when striking a ball in a range of positions across the club face. When the outcomes of the two tests were combined, a design was determined that demonstrates a reduction in roll distance variation to less than 1% at 20 mm from the central plane which is promisingly low compared to existing designs in common usage.

Further research is required to understand how the variation in face thickness may be tuned for more uniform roll distance independent of ball impact position, and to consider the trend of the COR data more closely by testing across more impact intervals. With this data it is expected that roll distance variation can be reduced further, producing a design with minimal variation across the entire clubface.

Acknowledgments: The authors would like to thank Tom Morris for the work conducted during his final year dissertation project forming the basis for this paper [13].

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