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Analyzing the characteristics of golf driver shafts with using a strain gage

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This study compared and evaluated the characteristics of golf driver shafts 60R products, manufactured by the most-used three companies and a domestic company adopting a new material process technology in the world. The characteristics of driver shafts were evaluated by observing the variations in golf shafts at an impact, which is known to influence driving distance and directional nature, by using a strain gage and a swing machine. Experiment results on four driver shafts showed that each shaft had different degree of deformation at an impact and formed different pattern at each position. Shafts of Autopower, Tour AD MT, and Fujikura showed an arch shape at an impact in overall. However, those of Attas revealed letter S shape. Under the test condition, Autopower shafts showed relatively higher bending stiffness and had the largest impulse on a ball. So it was expected that they would increase the ball speed after an impact.

Key words: Strain gage, Impact, Impulse, Bending stiffness, Golf driver shaft.

Introduction

Owing to the development of sports science, the sports performance has drastically improved in the last century. The performance of professional golf players has also steadily improved as well. Every golfer (highly) longs for longer driving distance and higher accuracy when playing golf. Manufacturers of golf clubs and golf balls have conducted various studies to find out the best materials and the superior manufacturing processes for clubs and balls to enable golfers to hit a golf ball the farthest distance and generate maximum club velocity. Studies on the golf can be roughly divided into two parts. One is the kinetic study regarding the system between a body and a gold club. The other is to study the relationship between a club and a ball. The former is to establish a correct golf swing motion, while the latter is to fabricate a high-performance golf club.

A golf club can be divided into three parts: a grip, a shaft, and a head. Among them, the head and the shaft decide the characteristics of a club. The head mass is an important factor determining the total weight of a golf club. A good shaft means a light shaft with maintaining the required strength. A club head tends to use light material and expand the size of part impacting with a ball and enlarge the sweet spot, so it can increase the precision and driving distance. The weight and strength of a shaft influence the driving distance and trajectory of a golf ball. Moreover, the flex, as well as the weight, is an important design variable in designing a shaft. The flex is a measure indicating the bending stiffness of a shaft. It is known to influence the driving distance and trajectory of a ball. The flex of a shaft is mainly measured and indicated by the natural frequency (i.e., cycle per minute (CPM)). The natural frequency of a shaft varies by the weight of a head and the length of a club. However, the CPM method for measuring the flex of a shaft cannot provide precise characteristics of a shaft because it does not provide deformation information for each part of a shaft.

Therefore, it is necessary to present a method that can determine the extent of current methods for determining the flexibility of the shaft being used, more accurate position another variation of the axis.

A shaft experiences 3-directional deformation during a golf swing. They are the twist due to the moment to the longitudinal direction, the Lead/Lag indicating the deformation parallel to the swing plane, and the Toe Up/Down representing the deformation perpendicular to the swing plane. These deformations are important in determining the trajectory of a golf ball. A strain gage has been used to measure these deformations of a shaft and it has an advantage in measuring the strength of a shaft more precisely during an impact. Previous studies evaluating the characteristics of a golf shaft using a strain gage were conducted by having golfers hit balls with various shafts with alternative weight and physical properties and measuring the landing point of balls. However, it was very hard to know if the difference in the driving distance was due to changes in physical properties of shafts or alternations in golfers'

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swing (i.e., head speed, swing tempo, back-swing tempo, forward-swing tempo, and back-swing distance) due to weight differences. However, it was determined that an experiment with a swing machine would be advantageous in comparing the physical properties of shafts because it does not have an acceleration effect and its swing pattern has same speed from the back-swing top to the impact.

Therefore, this study intend to provide baseline information for a more scientific and systematic golf club fitting system to select the most optimized shaft, which is known to influence the driving distance and directional nature, for improving performance by identifying the characteristics of each golf shaft after observing the variation in golf shaft at the impact with using a strain gage and a swing machine.*

Experimental

This study was conducted on 60R shafts made by famous foreign (i.e., Tour AD. MT, Fujikura Speeder 661, and Attas 4U) and domestic (i.e., Autopower) club shaft brands. Many golfers are most sensitive to the driver head and only Big Bertha (loft 10.5 ^{o}) model manufactured by Callaway was used for the study to minimize the changes in characteristics of shafts due to club head weight during a swing. The Titleist ProVIX golf ball was consistently used for the test. Furthermore, all shafts used for the test was made to be 45 inches long, which is the standard length of a driver club, after a club fitting expert precisely measured the length. Sleeve was attached at the shaft tip to attach and detach the driver head.

First, strain gages were attached at the 4 parts of each shaft to measure the deformation during the impact (Fig. 1).

In the swing experiment using a robot machine, the measured shaft deformation data only indicates the resistance value of strain gages. It just shows that deformation occurs at each part of a shaft. However, it does not provide any quantitative information. Therefore, the data should be calibrated to generate quantitative information regarding the degree of shafts' deformation. Calibration factor was estimated by hanging various weights on a shaft, which was fixed on a vise, and transferring the data to a PC after amplifying the stress gage signal. The acquired data was used for a standardization process to acquired quantitative information.

An Iron Byron Hitting Machine was used for the swing test. The swing speed of 60R, which was used for the test, was fixed to 100 mph. Moreover, swing spot of each shaft was adjusted by attaching stickers of Japanese Daiya Company to align the center of a head to a golf ball (Fig. 2).

Lastly, for measuring the variation of shafts with using a strain gage, the variation by the impulse during an impact was measured by repeating a test 3 times for each shaft by a manufacturer.

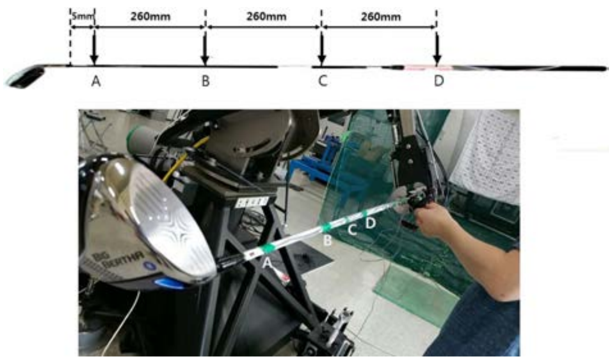

Fig. 1. Placement of strain gage attached to the golf shaft.

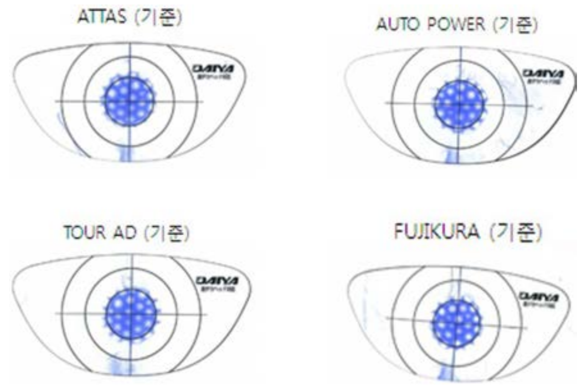

Fig. 2. Spot position of club heads used in experiment.

Results and Discussion

The average of the three measurements of strain variation for each position of a club shaft during Autopower shaft swing is shown in the Fig. 3. It is very important to find the moment of an impact from experimental data. As indicated in the introduction, a shaft experiences deformation to mainly three directions during a golf swing. The effects of longitudinal twist could be ignored in this experiment because consistent swing axis due to the usage of a swing machine. The effects of Toe Up/Down indicating the deformation perpendicular to the swing plane could be ignored as well because it was adjusted to precisely align the center of a head to the swing spot of all shafts prior to an experiment. Therefore, strain gage reading only showed the Lead/Lag deformation, which represents the deformation parallel to the swing plane. The moment of impact can be easily found from the experimental data because it is when the value of Lead/Lag abruptly changes. As the moment of impact is found, variation in a shaft at the moment of an impact can be observed. Hereafter, Lead and Lag are defined as positive value and negative value in all variations.

The 60R strain variation measured at the position A of a shaft by each manufacturer (fig 4). All shafts used

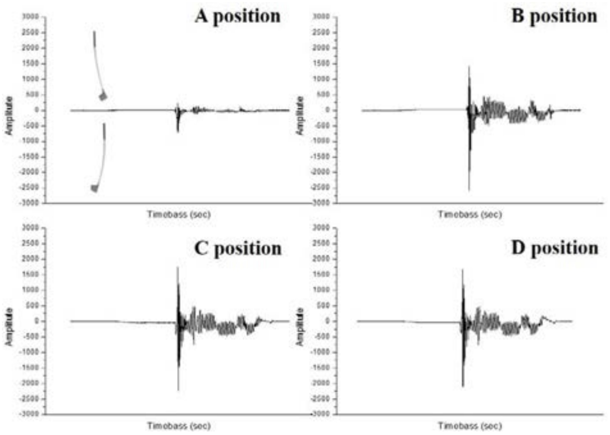

Fig. 3. Strain patterns of autopower shaft recorded for robot swings.

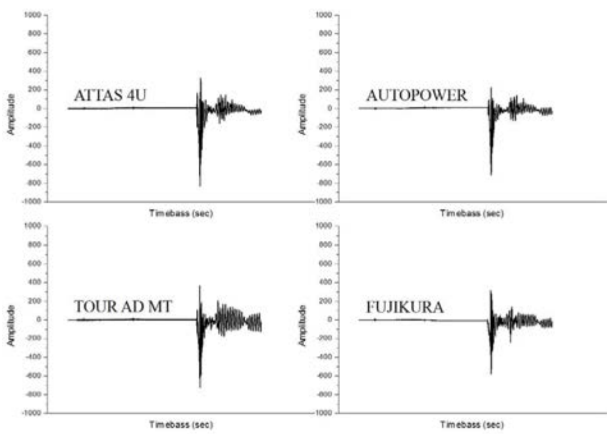

Fig. 4. Golf shaft strain patterns recorded for robot swings at A position.

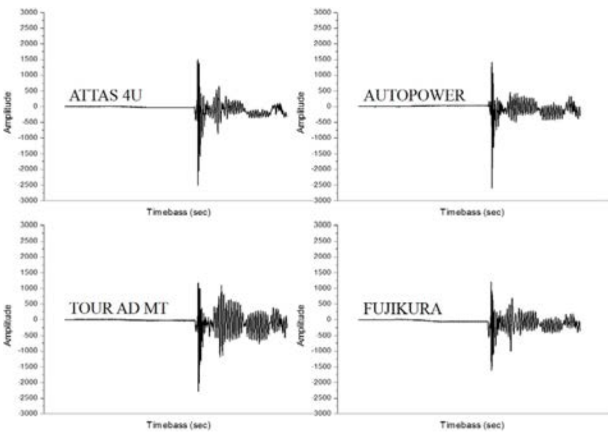

Fig. 5. Golf shaft strain patterns recorded for robot swings at B position.

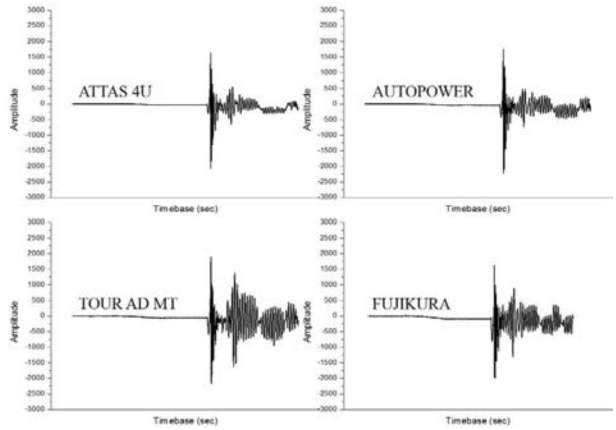

Fig. 6. Golf shaft strain patterns recorded for robot swings at C position.

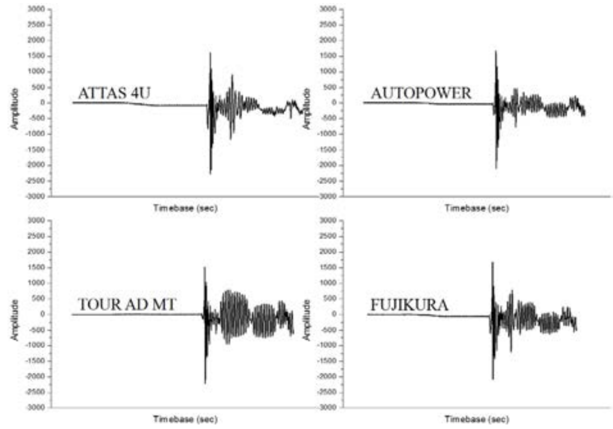

Fig. 7. Golf shaft strain patterns recorded for robot swings at D position.

for an experiment showed higher Lag (–) variation than Lead (+) variation at position A, which is close to a club head. Particularly, the Fujikura shaft showed less variation than other shafts. This means that it has smaller flex (or bending stiffness) than another shafts at the position A.

The strain variation measured at the position B of a shaft by each manufacturer (fig. 5). All shafts showed higher variation than previously measured variation at position A. Shafts of Autopower had the highest variation at position B, indicating good flex (bending stiffness). Contrarily, shafts of Fujikura showed the least variation. .

The strain variation measured at the position C of a shaft by each manufacturer (fig. 6). Attas and Autopower revealed that it was reduced from the measurement at position B. However, it slightly increased from the measurement at position B for Tour AD MT and Fujikura. Moreover, Attas and Autopower showed that variation during an impact rapidly decreased after an impact indicating high recovery power. However, variations of Tour AD MT and Fujikura at an impact decreased slower than those of Attas and Autopower, representing that the recovery power was relatively smaller. These results indicated that each manufacturer has different shaft manufacturing process for the same 60R shafts. The characteristics of Autopower and Attas 's 60R shafts are good flex from head to position B with low flex between position B and position C. On the contrary, Tour AD MT and Fujikura were manufactured to have similar flex from head to position C.

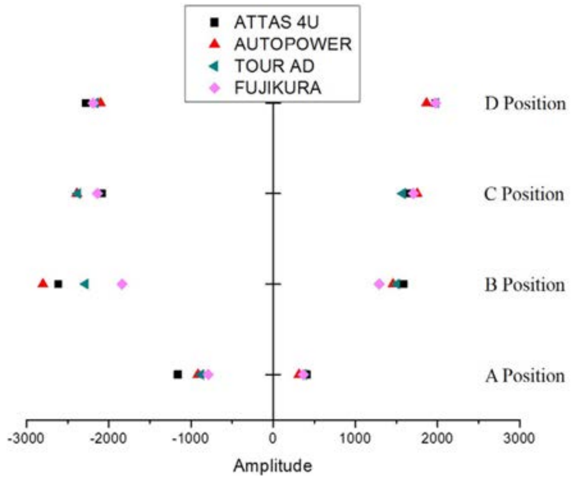

Fig. 8. Golf shaft variation at each position.

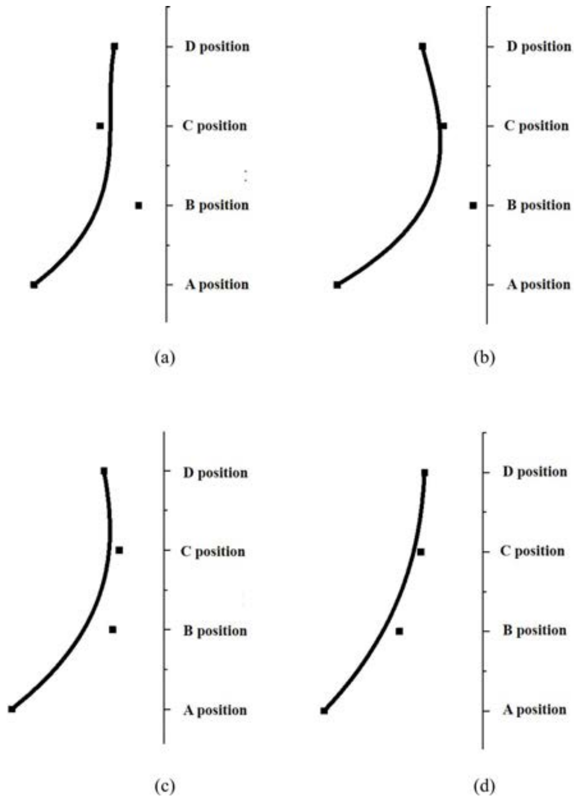

Fig. 9. A each Golf Shafts shape at impact: (a) ATTAS 4U, (b) AUROPOWER, (c) TOUR AD, (d) FUJICURA.

The strain variation measured at the position D of a shaft by each manufacturer (fig. 7). Similar variation was observed for all shafts at the position D, which is the farthest point from the head. Variations of shafts at impact for each position were shown in Fig. 8. When only positions A and D were considered, all shafts show an overall tendency to increase variation to Lead (+)/Lag (–) direction at the impact. At position A, deformation to the positive Lead (+) direction did not show much difference. However, Attas shafts showed slightly larger variation than other shafts to Lag (–)

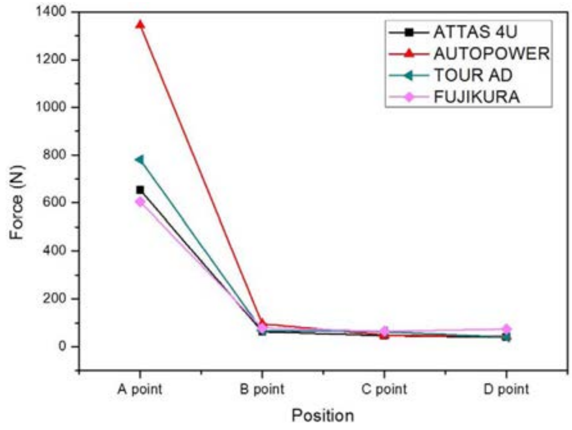

Fig. 10. The impulse measured at each position at impact.

direction. It can be determined that Attas shafts have high flex to the backward of swing direction at the position close to a head during an impact. It shows that bending stiffness toward Lag (–) direction at position B varies a lot among shifts. Especially, it was confirmed that Autopower shafts had the highest flex (bending strength) to Lag (–) direction and Attas shafts showed the highest changes to Lead(+) direction. At position C, it was found that Autopower shafts had the largest variation to both Lag (–) and Lead (+) directions. At positions A, B, and C, variations to Lag (–) were slightly larger than those to Lead (+), while variations were almost constant to Lag (–) and Lead (+) directions at position D. It could be confirmed that the flex of shafts used for the experiment varied by each position.

The overall shape of a golf shaft used for the test can be predicted by using the Lag (–) variation and it was shown in Fig. 9. The graph in Figure 9 was created by using the Bezier Curve based on data acquired from a strain gage. A golf shaft shows a different form to each other. ATTAS, AUTO Autopower POWER, and TOUR AD shafts show the highest bending stiffness at the position B. FUJICURA reveals constant bending stiffness over the whole shaft and has lower bending stiffness than other shafts. Particularly, Autopower shafts show higher bending stiffness at position B than other shafts. Moreover, ATTAS has high bending stiffness at position B but bending stiffness drastically decreased at position B, unlike other shafts. Measurement results of an impulse to a shaft at impact were shown in Fig. 10. The impulse at positions B, C, and D was almost identical, but it at position A was different one to another. The impulse at position A increases in the order of FUJIKURA, ATTAS, TOUR AD, and Autopower. Impulse measured by strain gage is closely related to bending stiffness and changes in strain gage [8]. Variations at position A (Figure 8) show that variations of all shafts are different from the impulse at the impact. It was believed that it was because impulse at an impact was measured at the position A but the impulse was transferred to positions

B and C following a shaft. Therefore, it influenced positions B or C to alter the radius of curvature, which indicating the bending of a shaft. As the results shown in Fig. 9, Autopower shafts received the largest impulse at position A to influence position B and show high bending stiffness at position B. In consequence, it had overall high bending stiffness than other shafts. TOUR AD showed larger impulse than ATTAS. Although ATTAS had high shaft variation than TOUR AD, it could be interpreted as a result of differences in bending stiffness at positions B and C. Lastly, FUJIKURA shows the least impulse and it agrees well with the overall low bending stiffness of FUJIKURA shafts as discussed previously.

Conclusions

This study observed the variation of four golf driver shafts at an impact by using strain gages and a robot swing machine. The results on four driver shafts experiment confirmed that each shaft had a different degree of shaft deformation at alternative positions at an impact. Autopower, Tour AD MT, and Fujikura form an arch shape at an impact in overall but Attas makes S shape at that point. It could measure the degree of shafts' deformation more precisely than the method to simply measure the flex of shafts through CPM. Therefore, it was determined that it would provide more precise information to golfers at various skill levels in selecting shafts. At the experiment condition, Autopwer shafts showed relatively higher bending stiffness than other shafts and had the largest impulse at the impact. It was believed that one could expect an increase in ball speed after an impact. This can be interpreted by reasons. First, it could be caused by the alternative head speed at an impact due to the differences in bending stiffness among positions of a shaft. Although this experiment controlled the velocity and pattern from the back-swing top to the impact by employing a robot swing machine, it was impossible to control the acceleration as well. If there were high bending stiffness at a position near to a head, it would increase the head speed (in a moment) at an impact (after back-swing and down-swing). Secondly, it can be explained as an efficient energy transfer. At an impact of a golf club head and a golf ball, a golf ball is deformed and a portion of energy is converted to push a shaft to backward. The shaft moves back toward the golf ball and it pushes the golf ball again. More energy can be transferred and efficient energy transfer can be acquired by this effect.

Therefore, when a golfer with same swing pattern and speed with this experimental condition selects a 60R shaft, the golfer may select a shaft with higher bending stiffness than lower bending stiffness to increase the driving distance by improving the ball speed after an impact.

Acknowledgments

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