THE EFFECTS OF GOLF SHAFT AND CLUBHEAD ON THE VELOCITY OF CLUB-HEAD AND BALL

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The purpose of this study was to investigate 1) the influence of the bending stiffness of the golf shaft on the velocity of the club-head and the ball, and 2) the influence of different club-heads on the velocity of the club-head and the ball. Four different drivers made up of two different shaft stiffness (R-stiff, L-flexible) and club head (Titanium, Graphite) were used in the experiments. The results showed that the shaft stiffness L resulted in slower before-impact club head velocity than the shaft stiffness R, whereas the shaft stiffness L resulted in higher maximum ball velocity than shaft stiffness R. But the result in the statistics showed no significant club-head material effect on either club-head velocity or the ball velocity. And there was no significant shaft stiffness effect on either club-head velocity or the ball velocity.

KEY WORDS: shaft bending stiffness, club head, golf

INTRODUCTION: The two major parts in golf club affect the club head velocity and ball velocity are club shaft and club-head. The role of club shaft is to transfer the force produced by the waist, shoulder, arm and wrist during the downswing to the club-head , The speed of the club-head comes from the force transferred by the club shaft. During the downswing, the grip suffered heavy stress in down direction; on the other side, the club-head also suffers the inertia force, the two forces make the club shaft bend. Masuda & Kojima(1994)have indicated that the kick back effect would decrease the speed of the club-head but the force of the shaft recovering would increase the speed just prior to the impact. The material of the flexible shaft can store more elastic energy than the stiff shaft. And if the stiff shaft doesn't suffer enough stress, it will store less elastic energy. For this reason, Milne(1990)thought that the weak swing should use the flexible shafts, and the strong swing should choose the stiff one. Because the strong swing had the faster speed in club-head, and the weight of the club-head and the stress of the shaft is enough to make the shaft become flexible. If the strong swing uses the flexible shaft, the shaft will be too flexible to store elastic energy. Thus this will make the club lose the control. Horwood (1994) has indicated that having the faster recovery of the shaft can increase the club head speed. The time in recovering is determined by the material of the shaft. And the process of recovery is determined by the timing of the swing, centrifugal force and inertia force. In the study of the dynamic performance of the golf shaft during the downswing (Butler & Winfield, 1994), it has been discovered that the centrifugal force caused the shaft to deflect in the toe direction just prior to impact. Therefore different handicap golfers should choose different club shafts to match their skill levels. The responsibility of club head is to transfer the energy by collision to golf ball prior to impact. But at impact, the face of the club head will be plasticity deformed and broken. Therefore the manufacturer aims at the study of the material of the club head stiffness to decrease the energy loss and strengthen the constant of the club-head. Tang(1994) has indicated that adding a hard inlay on the club-head face does not help the distance of the ball. In "The Physics of Baseball", Adair (1994) has stated that the distance of the flying ball hit by a slice of stiff steel attached to the hitting area of the baseball stick is shorter than the one without it. In the process of the collision, the energy transfers from an elastic material to an inelastic one will result in the energy loss. The material of golf ball is rubber with high coefficient of restitution, and the coefficient of restitution of titanium club-head is higher than golf ball. When the coefficient of restitution in the inlay is lower than the club-head, it does not help to increase the distance of a flying ball. Therefore the purpose of this study was to investigate the influence of golf shaft bending stiffness and club head stiffness on the velocity of club-head and ball during impact.

METHODS: The participant was an amateur golfer. The testing objects were four different drivers made up of two different shaft stiffness (R-stiff, L-flexible) and club-head (Titanium, Graphite) in the experiments (Table1). Data were collected and analyzed with a Redlake high-speed camera（1000Hz）and Peak Performance Motus32. There were three markers on the grip, the shaft bending point, and the club-head to analyze the kinematics parameters（Fig1.）The parameters were 1)the angle of the shaft bending, 2)the speed of the club head and 3) the speed of the ball . Each club is swung for twenty trials, and 10 trials were selected for further analysis. The club-head speed in 31~32m/sec was selected for analysis in this study.

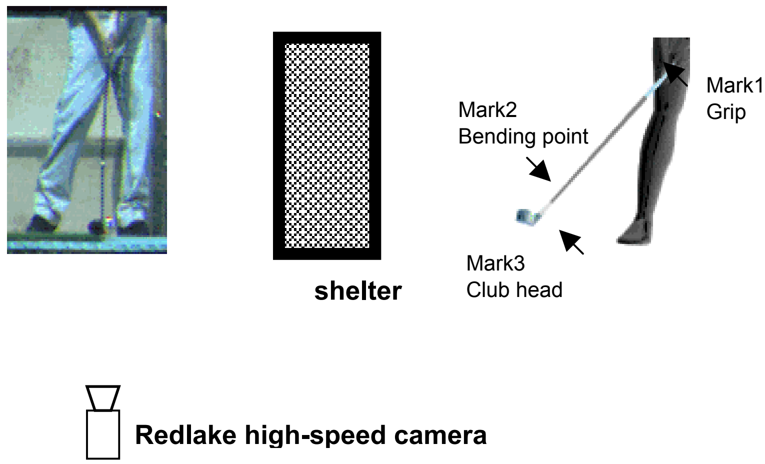

Figure1 - The arrangement of the experiment setup.

Table1 Test Shaft Specifications

Club head	Shaft-stiffness	Shaft-weight (g)	Club head-weight (g)	Grip-weight (g)	Swing-weight
Graphite	R	78.5	119	52.5	C8
Titanium	R	78.5	202	52.5	C8
Graphite	L	71.9	119	52.5	C8
Titanium	L	71.9	202	52.5	C8

RESULTS AND DISCUSSION:

The bending curve of shaft during downswing indicated that during the downswing the inertial forces will make the shaft go from a backward bending position to a forward bending position at the moment of impact (Fig2). And different stiffness will result in different levels of shaft bending (Table2) which is similar to Horwood's (1994) study.

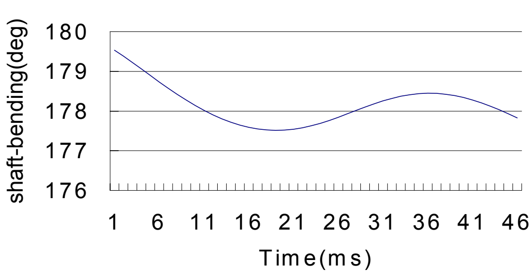

Figure 2 - The bending curve of shaft is during the downswing.

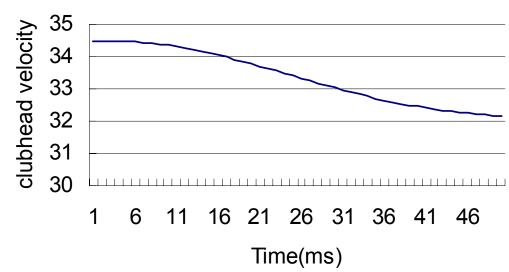

Figure 3 - The speed curve of the club head is during the downswing.

The speed curve of the club-head was captured from the middle of the downswing to impact. It showed that the speed of the club-head at impact was not the maximum (Fig3). The speed of the club-head went down. This finding showed that the kick-back effect would affect the speed of the club-head before impact which agreed with Masuda & Kojima's(1994) study. During the collision between the club-head and the ball, the club- head was slowed down and the ball was set off with a high speed. Prior to impact, the speed of the ball was not at maximum, but after microsecond, the speed of the ball went up (Fig4). We guess that in the process of the collision the ball was flattened against the club-head. Then the elastic properties of the ball come into play when the ball was compressed and then sprang away from the club-head.

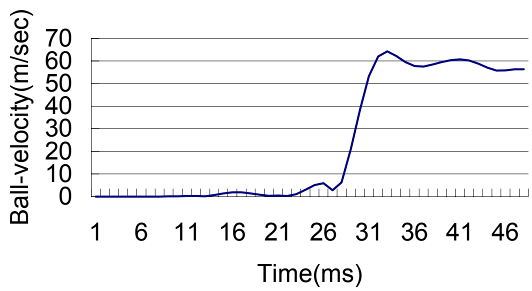

Figure 4 - The speed curve of the ball.

Table 2 Values for the Variables of the Four Samples

	R - Graphite	R -Titanium	L –Graphite	L –Titanium
The angle of shaft Min-ending (degree)	170.2±4.1	174.1±1.9	172.4±3.3	169.5±2.1
The angle of Shaft at impact (degree)	176.5±7.9	176.0±1.5	175.7±2.0	174.1±3.3
The velocity of Clubhead before impacting (m/sec)	32.3±1.2	32.5±0.5	31.7±0.7	31.1±1.0
Maximum velocity of ball (m/sec)	65.4±3.5	64.9±2.3	67.4±2.7	67.7±1.7

As shown in Table 2, the results in the speed of the club-head before impact the shaft stiffness R is faster than the shaft stiffness L, whereas the shaft stiffness R is slower than shaft stiffness L in the maximum speed of the ball. After using one-way ANOVA to determine the difference among 4 golf clubs with different shaft stiffness and club-head material combinations. We found that there was no significant club-head material effect on the speed of the club-head and ball. And there was no significant different shaft stiffness effect on both club-head velocity and the ball velocity.

CONCLUSION: The statistical results showed that the ball speed and club-head speed were not significantly different between different shaft stiffness (R and L) as well as different club-head materials (titanium and graphite). The results showed that when the speed of the club-head between 31~32m/sec, the stiffness of shaft had more effect on the ball speed and club-head speed than did the material of club-head. Furthermore, The shaft stiffness R (stiffer) resulted in a faster before-impact club head velocity than the shaft stiffness L, but the shaft stiffness R (stiffer) resulted in a slower maximum ball velocity than shaft stiffness L.

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