EXTRACTION OF DIFFERENCES IN DEFORMATION BEHAVIOR OF SHAFTS WITH DIFFERENT KICK POINTS

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A well-chosen golf club improves the shot and feel of the player. We aimed to clarify the factors that influence the feel when golfers swing shafts with different kick points. We hypothesized that the difference in feel occurs because the main deformation behavior changes with the difference in the kick points. Therefore, in this study, we calculated the shaft deformation using a simulation model and performed singular value decomposition (SVD). A finite element model developed in a previous study was used for the simulation [1]. We conducted a test to measure the grip movement during the swing. The test involved 17 participants (mean HDCP: +1 to 36). Informed consent was obtained in writing from the participants. Each participant used the same head but with different kick points (LOW/HIGH). The kick points were evaluated using the expression, inverse flex value / (inverse flex value + forward value), obtaining LOW = 48.4% and HIGH = 41.5%. We performed eight measurement trials on each shaft, in which they used a sponge ball to inhibit their feeling of hitting the ball and judging the trajectory. After the test, we conducted interviews with the participants to determine their preferred shafts. Then, we calculated the deformation behavior by inputting the grip movement into the simulation model. We used the deformation behavior of the shaft as the observation matrix $[R_a]$ and performed SVD using (1) [2].

$$[R_a] = \sum_{j=1}^{N} \lambda_j \boldsymbol{v}_j \boldsymbol{z}_j^{\,T} \tag{1}$$

where N is the number of elements in the model multiplied by three axes, λ_j, $\boldsymbol{z}_j$, and $\boldsymbol{v}_j$ indicate the contribution of each mode to $[R_a]$, position information of the node, and time information of $\boldsymbol{z}_j$, respectively. Through SVD, the calculated deformation behavior could be decomposed into two orthogonal deformations ($j = 1$ and $j = 2$). Figure 1 (a) shows an example comparing the deformation behavior using the local coordinate system, with the grip end as the origin. We confirmed the difference in deformation behavior when the kick point changed. Figure 1 (b) shows the differences in the main deformation behaviors and the direction of behavior changes between shafts. Therefore, we focused on the

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angle between the behavior direction at $j = 1$ and the x-axis (toe up/down direction), calculating the angles for all data. Table 1 shows the comparison results of the average values of each angle. Statistically significant differences (SSD) are marked with a circle, and the preferred shafts are listed. The LOW angles increased overall, indicating that the deformation of the x-axis decreased and the y-axis (lead/lag direction) increased relatively Participants who preferred HIGH shafts (participants F, G, H, I, J, L, O, and Q) tended to have angles < 45° and significantly higher LOW angles. During the downswing, the un-cock direction is along the x-axis. When the angles < 45°, the deformation of the shaft is likely to be along the un-cock direction . Further, with LOW shafts, the deformation along the x-axis decreased. Consequently, the deformation in the un-cock direction could not be felt easily; therefore, the participants preferred HIGH shafts. However, certain participants preferred LOW shafts under similar conditions, such as participants C and P. The reason for the decrease in the x-axis deformation with LOW shafts remains unclear. Therefore, in the future, we plan to include more participants and confirm the details of the behavior.

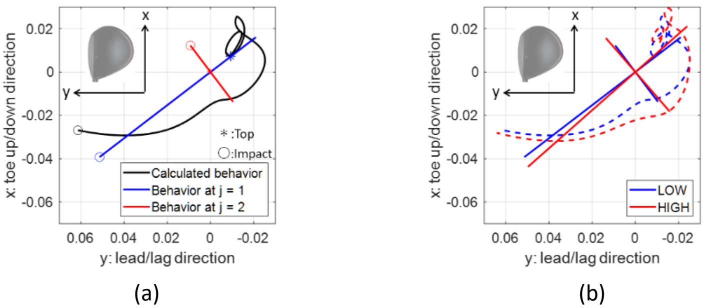

Fig. 1: Deformation behavior: (a) example result and (b) comparison result.

Table 1: Comparison results of the average angles of the shaft behavior and x-axis

Participants	Average LOW	Average HIGH	SSD	Preferred shfaft	Participants	Average LOW	Average HIGH	SSD	Preferred shfaft	Participants	Average LOW	Average HIGH	SSD	Preferred shaft
A	51	48	○	LOW	G	21	11	○	HIGH	M	27	26		HIGH
B	44	43		LOW	H	14	5	○	HIGH	N	26	26		LOW
C	37	30	○	LOW	I	42	32	○	HIGH	O	26	23	○	HIGH
D	41	39		LOW	J	20	17	○	HIGH	P	38	33	○	LOW
E	66	65		LOW	K	27	26		HIGH	Q	31	27	○	HIGH
F	41	38	○	HIGH	L	35	32	○	HIGH					

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2. Matsumoto K, Tsujiuchi N, Ito A, Kobayashi H, Ueda M, Okazaki K (2020) Proposal of golf swing analysis method using singular value decomposition, Proceedings 49(1):91.

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