EFFECTS OF DYNAMIC FRICTION ON OBLIQUE IMPACT BEHAVIOR OF GOLF BALLS

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KEYWORDS

Energy and friction in sport and leisure activities, oblique impact, golf ball, dynamic friction, sliding velocity, contact area

ABSTRACT

A previous study [1] investigated oblique impacts of a golf ball of mass m (46 g) and radius r (21.3 mm) with a rigid target inclined at an angle θ_i (30°) (Fig. 1a) and demonstrated the following: (i) the contact force N and area A rose in the early phases of the impact and then reduced in the later phases (Figs. 1b and c); and (ii) the angular velocity ω can depend on A and the ball centre velocity u_b. However, the dynamic friction F_d causes the shear deformation of the ball, and consequently the discrepancy between u_b and the contact centre velocity u_c. This study used the analytical model proposed for the dynamic sliding friction on lubricated and non-lubricated inclines [2,3]. The contact area A and the velocity u_c were used to describe the dynamic friction force $F_d = \lambda A u_c$, where λ is a parameter related to the wear of the ball surface [4]. This study proposed an elastic sphere model to understand the mechanism of shear deformation during oblique impacts.

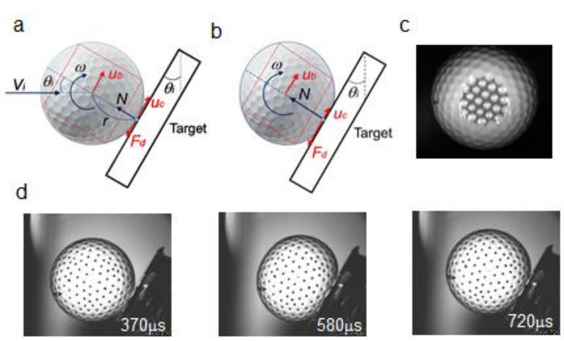

Figure 1. Impact behaviour of a golf ball. a, The rotating and sliding motion of the ball at impact. b, The compression and shear deformation of the ball during impact. c, High-speed image of the ball hitting a transparent PMMA target at an impact velocity $V_i = 32$ m s^{-1}. The image was photographed from the reverse side of the target. d, High-speed images of the ball hitting a steel target at $V_i = 37$ m s^{-1}. Markings were made on the dimples to enable ball surface measurement.

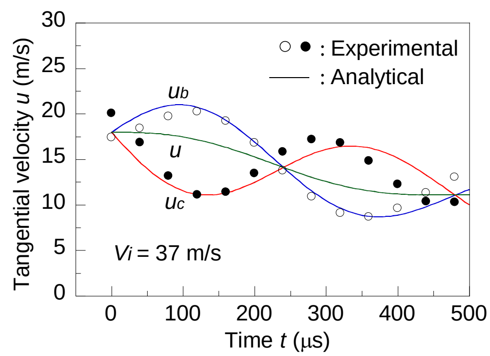

Figure 2. Tangential ball centre velocity u_b and contact centre velocity u_c for $V_i = 37$ m s^{-1}. u_c reduced in the initial phases of the impact, rose in the intermediate phases, and then reduced again in the final phases, whereas u_b showed the opposite trend.

Figure 2 shows the tangential ball centre velocity u_b and contact centre velocity u_c versus time t, where the experimental results were indicated with symbols; those derived from the proposed analytical model are indicated using solid curves. u_c showed three phases of noticeable velocity reduction, rise, and reduction once again. u_b showed the opposite velocity changes. The analytical velocities u_b and u_c are shown in Fig. 2. Although the analysis yielded discrepancies from the experimental results, the model represented all of the important qualitative features of the velocity changes at the ball centre and contact centre.

REFERENCES

[1] Arakawa, K. Effect of time derivative of contact area on dynamic friction, *Appl. Phys. Lett.* **104**, 241603 (2014).
[2] Arakawa, K. Dynamic sliding friction and similarity with Stokes' law, *Tribol. Int.* **94**, 77–81 (2016).
[3] Arakawa, K. An analytical model for dynamic sliding friction of polytetrafluorethylene (PTFE) on dry glass inclines, *Wear* **356–357**, 40–44 (2016).
[4] Arakawa, K. An analytical model of dynamic sliding friction during impact, *Scientific Reports* **7**, 40102 (2017).