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Hopping Leg Design Using Crank-Slider Mechanism

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I. Motivation, Problem Statement, and Related work

Animals in nature use dynamic gait to achieve fast locomotion on rough terrains. During the dynamic gait, legs make an impact on the ground when the legs touch the ground. The impact force generates a ballistic flight state: the state when all feet leave the ground. Several researches on adopting the dynamic gaits to robotic platforms have been studied; for instance, legged robots by Raibert *et al.* [1, 2], SCOUT2 [3], and PAW [4]. Most of the robots use pneumatic actuators to achieve the powerful impact on the ground; however, the robots have limitations of relatively large size and huge noise from the pneumatic actuators.

Objective of the research is to develop a light-weight hopping leg for the dynamic gait by using electric motors with crank-slider mechanism. Instead of using pneumatic actuators, we used an electric motor to generate the powerful impact on the ground for high hopping. A crank-slider mechanism transforms continuous rotating actuation of the electric motor to repeated linear actuation in hopping direction. A linear spring at the end of the hopping leg performs storing and releasing potential energy. The rest of the paper explains principles and experiments on the research.

II. Technical Approach

The hopping leg consists of the crank-slider mechanism and the linear spring, as shown in Fig. 1. The crank-slider mechanism converts rotational actuation by the electric motor into linear actuation of the slider (l_3). The actuation of the slider makes a powerful impact on the ground during touching the ground. The linear spring helps the hopping by storing potential energy when the leg lands. By the linear spring, the hopping leg partially performs SLIP model [5] which is well known for the model on dynamic gaits of animals. In conclusion, the hopping leg achieves high hopping from the powerful impact by the crank-slider mechanism and the linear spring.

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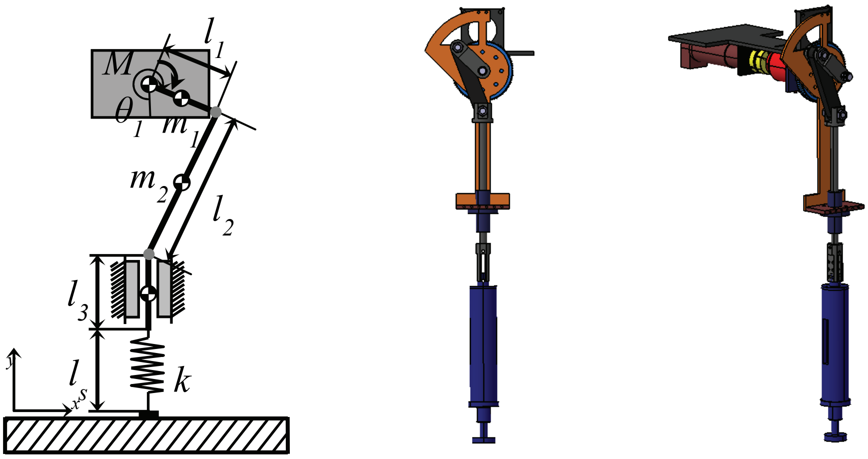


Fig. 1 Hopping leg design using crank-slider mechanism. The dimensions of the prototype are 370(L)×200(W)×560(H) mm^3.

III. Result

We performed dynamic simulation on the hopping leg by *Recurdyn* (http://www.functionbay.co.kr/, Function Bay Inc.) as shown in Fig. 2. Through the simulation, we know that the crank arm angle (θ_1) when the foot touches the ground highly affects the hopping height. Therefore, we perform an optimization on the crank arm angle to find the optimal value to maximize the hopping height. Resulting optimal crank arm angle is determined by 270 degrees while the jumping height is 419.2 mm (75% of prototype height)

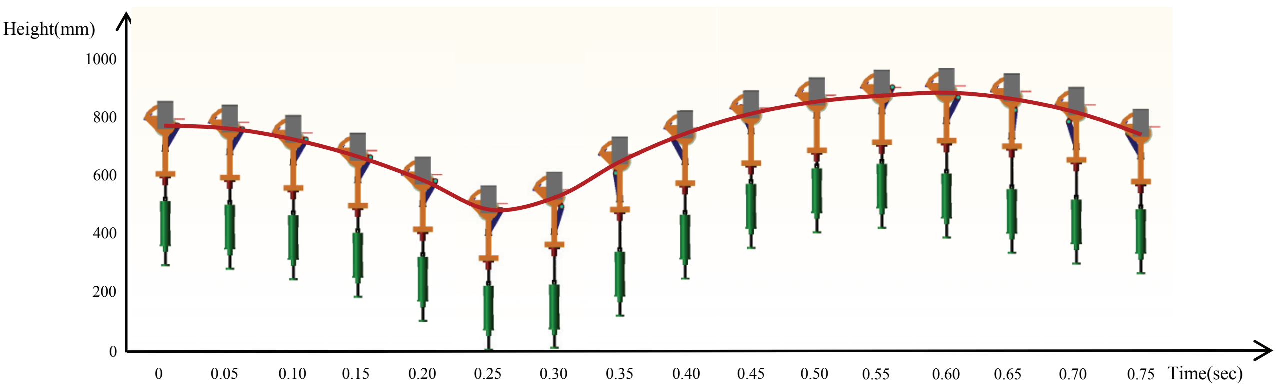


Fig. 2 Result of dynamic simulation.

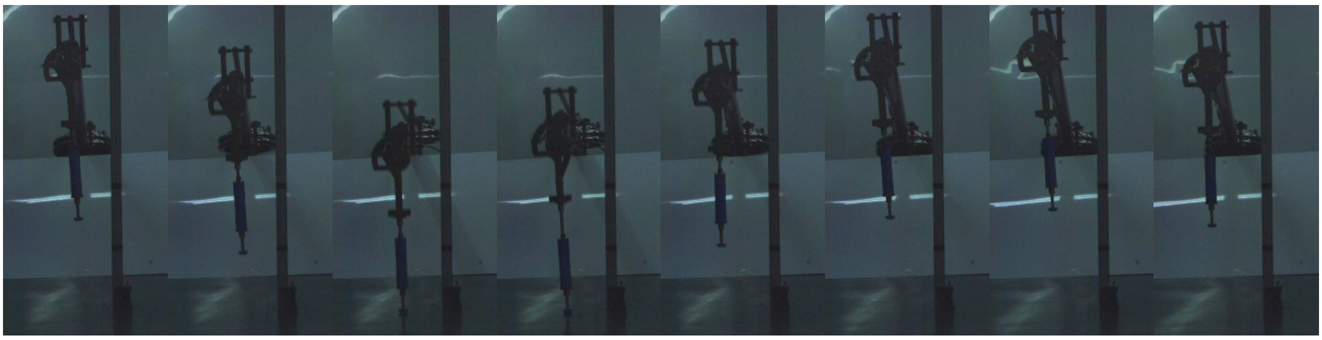
IV. Experiments

We made a prototype of the hopping leg as shown in Fig. 3. The size of the prototype is 370(L)×200(W)×560(H) mm^3 and the weight is 2.75kg. Brushless DC motor (Maxon, Fig. 3 a)) is used as the rotational actuator. A clutch (Fig. 3 b)) with holding equipment with switch (Fig. 3 c)) is used to maintain the optimized constant crank arm angle in repeated hopping motion. The spring with linear guide (Fig. 3 d)) is used to storing and releasing the potential energy during the hopping motion. Repeated hopping with a constant hopping height is possible by the prototype, and the posture of hopping is presented in Section V.

Fig. 3 Prototype: a) motor, b) clutch, c) holding equipment with switch, and d) spring linear guide.

V. Main Experimental Insight

The posture of the hopping locomotion of the prototype is shown in Fig. 4. As a result, the hopping leg can perform repeated hopping with a constant jumping height of 315 mm (56 % of prototype height). Note that the simulation results give us 419.2 mm jumping height; we think the difference is mainly due to friction and alignment error in the experiment. In conclusion, the prototype can achieve repeated hopping locomotion of high hopping height by the powerful impact on the ground using combination of the crank-slider mechanism with the electric motor and the linear spring.



0.00sec 0.16sec 0.32sec 0.48sec 0.64sec 0.80sec 0.96sec 1.12sec

Fig. 4 Experimental results on the hopping motion.

VI. References

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