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Oblique impact for flexible robotic finger system

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Abstract: A new contact model which takes account of the normal and the tangential compliance of the local contact zone is proposed to depict the oblique impact effect for the flexible robotic finger system in this paper. By the use of the proposed contact model (LCCM) incorporating with absolute nodal coordinate formulation (ANCF), the oblique impact mechanism is analyzed. The results show that multiple transitions between compression and resititution appear through a single oblique impact event. In addition, it also shows that falling height, coefficient of friction and energetic coefficient of restitution all have a significant effect on the peak vaule of contact force and the duration time of contact.

Key words: absolute nodal coordinate formulation; flexible robotic finger system; frictional contact; oblique impact; local compliance contact model (LCCM)

1. Introduction

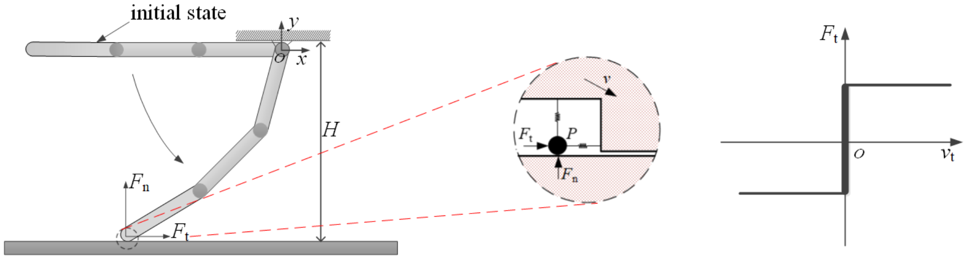
The oblique impact with friction will happen inevitably when a flexible manipulator grasps things. It will bring vibration with high frequency vibration, the propagation of the transient waves and high amplitude contact force which will lead to many adverse effects such as structural failure, noise increasing and safety decreasing[1]. Hence, many researchers pay attention to oblique impact, but the methods they used all have their own shortcomings. e.g. Djerassi[2] neglects the duration of contact-impact. And Shen and Stronge [3] negelect the elastic deformation of the rest of link, where is far away with the local contact zone. This paper proposes a new contact model incorporating with ANCF to overcome the previous shortcomings.

2. Methods

The finger system studied in this paper consists of three links as shown in Fig. 1(a), the system's parameters are shown in Tab.1. The ANCF incorporating with the LCCM[4] (see Fig. 1(b)) are used to study the oblique impact mechanism of flexible robotic finger system. The final dynamic equations are derived.

$$\boldsymbol{M}\ddot{\boldsymbol{q}} + \boldsymbol{\Phi}^{\mathrm{T}}\boldsymbol{\lambda} + \boldsymbol{K}\boldsymbol{q} = \boldsymbol{Q} + \boldsymbol{F} \tag{1}$$

where $\boldsymbol{M}$, $\boldsymbol{K}$ and $\boldsymbol{\Phi}$ are three-link system's mass matrix , stiffness matrix and displacement's constraint matrix, respectively. $\boldsymbol{\lambda}$ is lagrange multiplier, $\boldsymbol{Q}$ is generalized external force, $\boldsymbol{F}$ is the matrix of the external force, including the normal and tangential contact force. The contact forces are obtained by the LCCM. When calculating the frictional force for the sliding state, Coulomb friction model is used (see Fig. 1(c)).



(a) The flexible robotic finger system model (b) Local complaint contact model (c) Coulomb friction model

Fig. 1: The model for flexible robotic finger system with oblique impact

Tab.1: Three-link finger system parameters

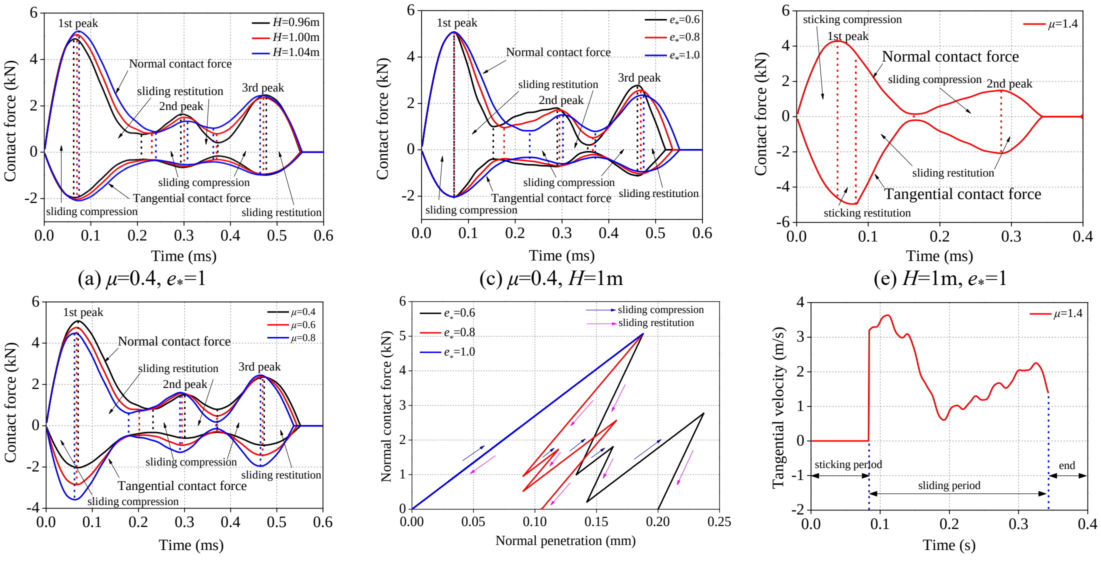
Elastic modulus E	Cross-sectional area A	Moment of inertia I	Density ρ	Length of i-th link l_i
7×10^{10}Pa	5×10^{-4}m^2	2×10^{-8}m^4	2700kg/m^3	0.4m

3. Numerical simulation results

To analyze the influence of fall height H, coefficient of friction μ and energetic coefficient of restitution e_* on the oblique impact event, we calculate the contact forces, normal penetration, tangential velocity of the particle in the LCCM and trajectory of fingertip under various values of H, μ and e_*.

3.1 Contact forces

Figs. 2(a), (b) and (c) are the normal and tangential contact forces under different system parameters. Figs. 2(a) and (b) are shown that all the normal contact force curves have three peaks, the 1st peak value of normal contact force will increase as increasing H and μ. And Fig. 2(c) shows that e_* doesn't affect the 1st peak, but the 2nd and the 3rd peak value will increase as e_* increases. Comparing with the curve of e_*=0.6, the 2nd peak value of e_*=0.8 will increase 13.3%, and the 2nd peak value of e_*=1 will increase 20.0%. Furthermore, the 3rd peak value of e_*=0.8 will increase 8.9%, and the 3rd peak value of e_*=1 will increase 17.8%. When $\mu\le0.8$, the tangential relative motions are only in sliding state. However, when μ=1.4, the tangential motion state occur sticking period, the specific motion state can be seen in Fig. 2(e). Meanwhile, the contact forces only have two peaks. And the tangential velocity of the particle is in Fig. 2(f).



(a) μ=0.4, e_*=1 (c) μ=0.4, H=1m (e) H=1m, e_*=1

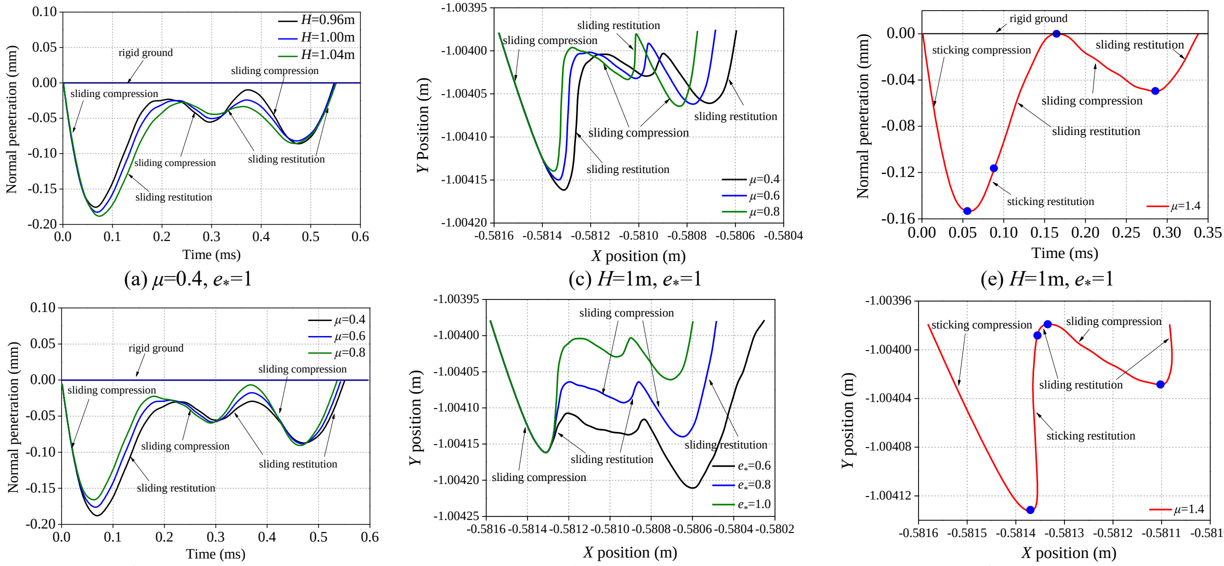
(b) H=1m, e_*=1 (d) μ=0.4, H=1m (f) H=1m, e_*=1

Fig. 2: Contact forces, tangential velocity of particle and multiple transitions between compression and restitution

3.2 Multiple transitions between compression and restitution

Figs. 3(a), (b) and (e) are the normal penetration of fingertip against the rigid ground. Figs.3 (c), (d) and (f) are the trajectory of fingertip during the whole oblique impact. Fig. 3(b) shows the ending time will decrease with increasing of the coefficient of friction. Concretely, the ending time is around 0.551ms for μ=0.4, 0.542ms for μ=0.6, and 0.536ms for μ=0.8.

Figs. 3 also shows the oblique impact experience multiple transitions between the compression state and the restitution state for the normal relative motion (see Fig. 2(d)). This is resulted from the structural bending compliance of the whole link. If it is neglected, it is hard to calculate the correct curve of the contact forces.



(a) μ=0.4, e_*=1 (c) H=1m, e_*=1 (e) H=1m, e_*=1

(b) H=1m, e_*=1 (d) μ=0.4, H=1m (f) H=1m, e_*=1

Fig. 3: Normal penetration and trajectory of fingertip

4. Conclusions

Be different from the hard body, because of the structural compliance of the finger, the oblique impact will experience multiple transitions between the compression state and the restitution state for the normal relative motion. And the tangential motion state has a sticking period once μ=1.4. Morever, the results show that falling height, coefficient of friction and energetic coefficient of restitution all have a significant effect on oblique impact.

5. References

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