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Influence of Initial Stress on Indentation Process

Basic parameters are chosen to be the same as those in Chen and Chen (2025) and Chen et al. (2025), except for initial stresses. We may set the initial stresses in x-direction as σ_0. A frictionless cylindrical indenter with radius $R = 4(\mathrm{m})$ and center coordinate $x_0 = 0(\mathrm{m})$ is applied on the same plane as Chen and Chen (2025) and Chen et al. (2025). The force-depth relations and variations of the contact area for different cases are depicted in Fig. 1(a) and (b), respectively.

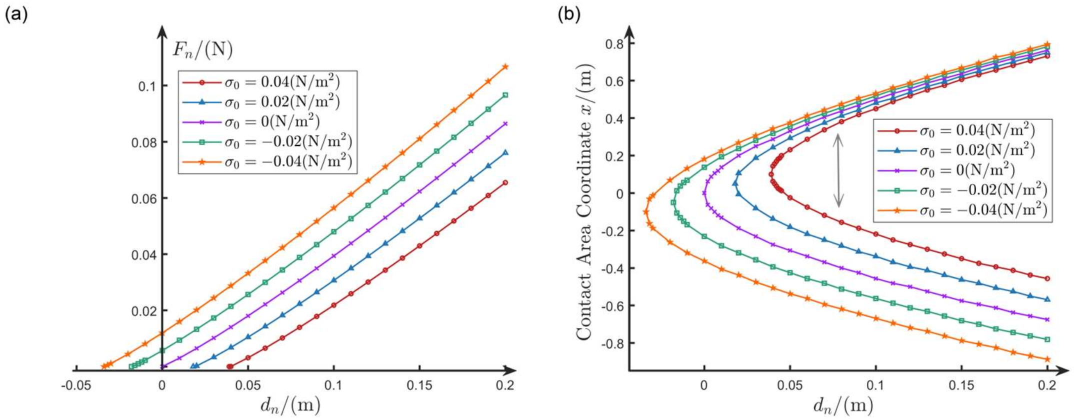

Fig. 1. Contact analyses of a finite-sized plane under different initial stress: (a) force-depth relations; and (b) contact area. The criterion for determining contact area between an indenter and the plane in (b) is $d_{\mathrm{gap}} < 10^{-4}$.

We find that the initial stresses change the contact relations by altering initial deformations of the plane, as shown in Fig. 1(a). Compressive/tensile stresses cause the indenter to contact the surface soon/late, respectively. Besides, the center of contact also transforms from less than 0 to greater than 0 as the initial stress changes from compression to tension. In addition, initial compressive or tensile stresses will lead to the pile-up or sink-in phenomena, which can be observed from contact areas respectively. The contact area is generally larger on the harder side of the plane, however, as the initial compressive stress increases, the contact area on the softer side grows faster and in some cases is larger than that on the harder side.

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