The strength of an adhesion cluster between two plates

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We present a theoretical model to study the lifetime $T(N_t, f)$ of an adhesion clusters under external force F, where N_t is the cluster size and $f = F/N_t$. The cluster is composed of N_t parallel ligand-receptor pairs. We find a characteristic force f_c predicted by the rate equation. By Monte Carlo simulation, we show (i) When $f > f_c$, T is independent of N_t. This can be explained by the rate equation which predicts that the fraction of connected ligand-receptor pairs $n_b(t)$ depends on f, but not on N_t. (ii) When $f = f_c$, $\ln T(N_t, f) \sim \ln N_t$. To explain the result we construct the effective free energy G and treat the force pulling process as a particle moving under G in N_b space. $G(f = f_c)$ has a flat region where the particle spends most of its lifetime to cross it. By estimating the width of the flat region with dimensional analysis, we find $\ln T(N_t, f) \sim \ln N_t$. (iii) When $f < f_c$ regime, $\ln T(N_t, f) \sim N_t$ because $G(f < f_c)$ has a barrier with barrier height $\sim N_t$ and lifetime T comes from the barrier crossing time of the particle, as a result $\ln T(N_t, f) \sim N_t$. Finally we show that the above three relations exist as long as the rebinding and unbinding rates are functions of f and n_b.

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