Tensile Strength of Porous Dust Aggregates Measured with Dust N-body Simulations

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In protoplanetary disks, formation process of μm-sized dust grains into km-sized planetesimals has several theories such as direct coalescence growth and concentration due to instability, and has not yet been unraveled. Also, we cannot directly observe planetesimals and restrict the formation process by observation of protoplanetary disks and exoplanets. Therefore, we focus on comets which are the most primitive objects in the solar system and are thought to be survivors of planetesimals. In recent years, tensile strength has been measured by the search results of comet 67P/Churyumov-Gerasimenko in the solar system. The tensile strength of planetesimals depends on their composition and formation process, and by investigating the tensile strength, the planetesimal formation process can be confined. Moreover, tensile strength is applicable not only to the planetesimal formation process but also to calculations of collisional destruction of dust grains and planetesimals.

Therefore, we conducted an N-body calculation considering the direct interaction of dust particles (Wada et al. 2007, ApJ, 661, 320) and investigated the tensile strength of porous dust aggregates. The dust aggregates as the initial condition were assumed to be ice with 0.1-μm-sized constituent particles and compressed by simulating their formation process (Kataoka et al. 2013, A&A, 554, A4). Also, though comets are considered to be sintered, in this research we assumed the case without sintering as the first step. As a result of the numerical calculation, tensile stress gradually increases as tensile displacement increases, and the tensile stress takes the maximum value at the time when the volume filling factor decreases to about a half of the initial value. In other words, the tensile strength was obtained. It was also confirmed that cutting of contacts between particles in dust aggregates begins to occur near the maximum tensile stress. The tensile strength is ~ 7×10^3 Pa when the initial volume filling factor is 0.1. This value is about 14 times larger than the compressive strength ~ 5×10^2 Pa when the volume filling factor is 0.1. This indicates that dust aggregates have a property that can withstand tension rather than compression. This difference can be explained by the fact that the compression of dust aggregates proceeds with rolling displacement between particles with a relatively weak stress, whereas the tensile strength is determined by the cutting of contacts between particles which requires a strong stress. In this talk, we will also discuss the dependence of tensile strength on the initial volume filling factor and on particle interaction model.

Keywords: Protoplanetary disks, Planetesimals, Comets, Tensile Strength