Introduction: Near-Earth asteroid (29075) 1950 DA is currently considered to be among the most hazardous asteroids due to its close encounter to the Earth in 2880 [1]. Busch et al. [2] conducted comprehensive radar observations of this asteroid and derived two possible shape models, a prograde model and a retrograde model. Farnocchia & Chesley [3] reported that the orbital semi-major axis of 1950 DA has been changing due to the Yarkovsky effect and confirmed that the retrograde model was consistent with their analysis. Because of its spin period, 2.1216 hr, this object may be close to its structural failure point if this body is a rubble pile. If 1950 DA has no cohesion, the bulk density should be higher than 3.5 g/cm$^3$ to prevent the body from failing structurally [2].

Rozitis et al. [4] reported that 1950 DA is a rubble pile and requires a cohesive strength of at least 44 Pa to 74 Pa to keep from failing due to its fast spin period. They analyzed its internal structure using Holsapple’s averaging technique. Since this technique considered the averaged stress over the whole volume, it discarded information about the asteroid’s failure mode and internal stress condition. This paper develops a finite element model and revisits the analysis of the failure condition of 1950 DA by Rozitis et al. [4].

Techniques: Holsapple [6] developed a finite element model, including plastic deformation characterized by the von Mises yield criterion to consider the failure condition of a rotating, non-gravitating ellipsoid. We extend his model to a model that can take into account self-gravity and plastic deformation characterized by the Drucker-Prager yield criterion. For our computations we use a commercial finite element software, ANSYS, version 15.03. For the modeling, we do not consider material-hardening and softening. Under the assumption of an associated flow rule and uniform material distribution, we identify the deformation process of 1950 DA when its constant cohesion reaches the lowest value that keeps its current shape. We investigate the internal condition of the 1950 DA retrograde model at the current spin period.

Results: The results show that for the bulk density estimated by Rozitis et al. [4], 1.0 g/cm$^3$ - 2.4 g/cm$^3$, to avoid structural failure the internal core requires a cohesive strength of at least 75 Pa - 85 Pa. It suggests that for the failure mode of this body, the internal core first fails structurally, followed by the surface region (see Figure 1). This implies that if cohesion is constant over the whole volume, the equatorial ridge of 1950 DA results from a material flow going outward along the equatorial plane in the internal core, but not from a landslide as has been hypothesized (see Figure 2). Thus, the body’s failure state is not close to either surface material being shed or landsliding. Also, given that plastic flow will in general increase volume in an associated flow rule [7], this failure mode predicts that the central core of the asteroid may have a reduced density, which is a previously unpredicted state for such oblate, rapid rotators.


Figures:

Figure 1 Stress solution. The value from 0.99 to 1.001 shows plastid deformation (the internal core).

Figure 2 Total deformation vector in meters.