COMPACTION AND STICKING OF PLANETESIMALS DUE TO POROSITY.
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Introduction: Planetesimals were formed by collisional growth of dust aggregates in the midplane of the protoplanetary disks. Accretional processes of planetesimal formation ranging from micrometer-sized dust particles to kilometer-sized planetesimals have been poorly understood, up to date. Collision velocity of small planetary bodies is 50 m/s or more [1,2]. These energetic collisions should lead to the powerful deformation or complete fragmentation of colliding bodies. These outcomes have been verified by means of many experiments and are very sensitive to the configuration of pre-collision fractures and voids in the bodies [3]. In the initial phase of planet formation, the dust particles are very porous, in which the grain porosity may reach 91-94% [4]. The impact compression of dust aggregates results extremely fluffy aggregates [5]. Some asteroids show the rubble pile structure (volume proportion of internal voids may reach 40-50%). Role of the porosity may become important respect to sticking of planetary bodies.

The kinetic energy of colliding bodies was transformed into other type of energies as follows. (1) Deformation energy is performed by the compaction due to porosity (below collision velocity limit is given). The purpose of this study is to examine the collision and compaction of planetesimals with respect to porosity (model a). Furthermore we have made models from mass- and number proportions of planetesimals in the early Solar System.

Our numerical models: (a): We examined the central type collision of idealized planetesimal models (P_1 and P_2, seen Fig. 1) at intermediate velocity (v_1=20 m/s; v_2=10 m/s) with porosity in the range φ_1=0,2; φ_2=0,1.

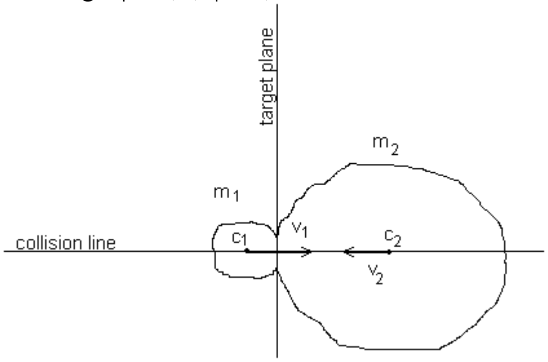

Figure 1: Central type collision of idealized models P_1 and P_2. C_1 and C_2 are the mass centers and vertical axis is the common target plane of two planetesimal models.

We calculated compaction work using our porous compaction model. Further parameters of planetesimal models are as follows: $Ø_1$=30 km, $Ø_2$=100 km (approaching to spheriform); mainly silicate-, in less degree metal-oxide composition; averaged densities ρ_1=2,16 kg/m^3, ρ_2= 2,43 kg/m^3 (after inclusion of porosity) and calculated masses $m_1=3{,}054\cdot10^{16}$ kg, $m_2=1{,}272\cdot10^{18}$ respectively. Volume of one planetesimal model is calculated as follows:

$$V_p = \sum_{x=1}^{n} V_{xr} + \sum_{x=1}^{n} V_{xp} = V + V_{ep} \qquad (1)$$

Where V_P is the volume of planetesimal, V_{xr} is volume of xth internal rock-block V_{xp} is the volume of x pore, V is the complete volume of internal rock blocks and V_{ic} the complete volume of pores, respectively.

Model (b): We estimated with numerical methods that numbers, sizes and masses of planetesimals in mass are ranging from 10^{16}-10^{20} kg to boundary of the early inner solar system. Similarly, we considered the planetesimal masses were scattered by means of perturbations of proto-Jupiter from the terrestrial zone. Following this, the calculated mass proportions and their related averaged porosity values were determined.

Results: (a) The escape velocity at point of contact is calculated as follows: v_e= $3{,}56\cdot10^{-2}$ km/s.

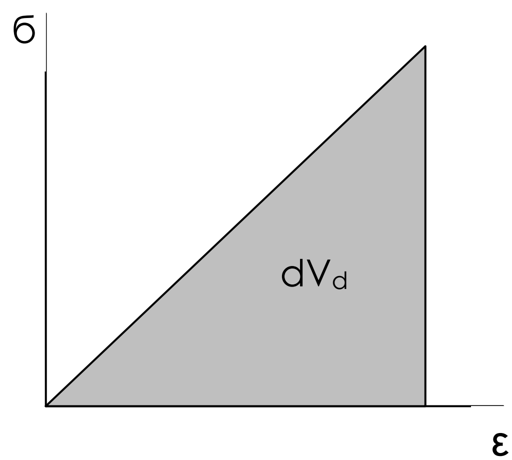

Figure 2: Tension-deformation curve of a collisional process in the idealized planetesimal models P1 and P2.

Deformation work (Fig. 2) is also calculated:

$$W_d = {}^1/_2 \int \varepsilon\sigma dV_d \qquad (2)$$

where ε is the degree deformation, σ is degree of tension in internal structure due to collision and V_d is the volume of deformation. The efficiency of deformation work by given conditions is:

$$\eta = \frac{W_u}{W_e} \qquad (3)$$

Where η is the efficiency of deformation work, W_u the useful work, W_e is the expended work. We could get following results: the value of useful work is $1{,}342 \cdot 10^{19}$ J and expended work is $1{,}374 \cdot 10^{19}$ J. The efficiency of deformation work is 97,65 %. The loss of the work (W_L) is $3{,}2 \cdot 10^{17}$J, which was transformed into thermal energy.

We experienced that compaction was not occurred when the collision velocity was exceeded significantly into the escape velocity. Conversely as less velocities (10,20 m/s) compaction occured is inside structures by pressure waves inwards from contact zones in the direction of mass centers. In case of central type collision, the fragmentation and the mass loss (due to the surficial erosion) are negligible as the collision velocities, too. Compared to other outcomes of deformation energy, energy consumption of compaction is relatively high. The compaction efficiency of deformation work is influenced by the porosity. At the same time, fast collision of rubble pile planetesimals are not occurred, but it indicates fragmentation.

In our model the compaction efficiency (η_c) and the efficiency of deformation (η) are almost equal with each other ($\eta_c < \eta$), because the fragmentation and eroded mass loss have the minimum value.

Discussion: (b) According to our numerical simulation (Fig. 3), at least seven large protoplanets were revolved in the inner solar system in the beginning of solar system formation. In case of mass range 10^{16} kg the numbers of planetesimals ($4 \cdot 10^8$) was relatively high. Mass of planetesimals and protoplanets in the terrestrial zone was estimated as $1{,}2 \cdot 10^{25}$-10^{26} kg. Decreasing value of porosity is proportional with the mass growth of planetesimals. Moreover several intermediate-sized planetesimals had high porosity due to the rubble pile structure. Our calculation shows that the protoplanets were not porous due to collision-compaction processes.

Summary: The porous structure increase compaction efficiency of deformation work by collisions. In this manner the porosity can support the sticking of bodies and we expect that this feature play am important part in formation and further growing of the planetesimals. The collision stickings will make larger bodies gradually and the largest planetesimals continue to grow into spheriform protoplanets.

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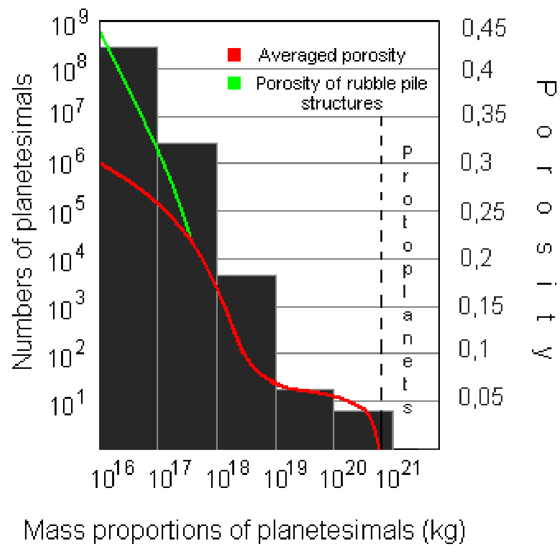

Figure 3: Distribution of planetesimal masses in the initial phase of protoplanet formation inside the solar terrestrial zone.

References:

[1] Weidenschilling S. J. and Cuzzi J. N. (1993) *in protostars and planets III,* 1031-1060. [2] Sekiya M., Takeda H. (2003) *Earth Planets Space, 55,* 263-269. [3] E. Asphang, S. J. Ostro, R. S. Hudson, D. J. Scheeres, W. Benz, (1998) *Nature 393,* p 437-440. [4] Graham J. R., Kalas P. G., Matthews B. C. (2007) *the Astrophysical Journal, 654:* 595-605. [5] Suyama T., Wada K., Tanaka H. (2008) *LPS XXXIX, Abstract #*