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衝撃応力HEL-0.7GPaにおける氷のユゴニオの解析手法

A method of Hugoniot estimation of ice between HEL and 0.7 GPa

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HELから0.7GPa領域の氷の衝撃波は、先行弾性とメイン衝撃波からなる複雑な波形を示し、メイン衝撃波の立ち上がりが鈍いのが特徴である。この特徴は、これまでに測定された氷のユゴニオから、HELから0.7GPa領域の衝撃波速度が衝撃圧力の増加とともに減少しているためであると考えられる。本発表では、この衝撃波と衝撃圧の関係が単調減少すると仮定して、この領域の氷のユゴニオを計算する方法について提案する。

Planets and satellites in the outer solar system mostly consist of water ice and solid bodies generally have many craters on their surfaces. The impact phenomena of ice is one of the most important physical processes in the formation of icy bodies. To understand the impact phenomena of ice, we required the Hugoniot of ice.

An observed shock wave of ice with a peak shock stress lower than 0.7 GPa showed a complicated wave structure: it had a precursor wave followed by a main wave longer stress rise-time and higher stress amplitude. This wave structure indicates that the shock velocity above 0.7 GPa decreases with increasing the shock stress as shown in the previous Hugoniot of ice (see Gaffney 1985). As the main wave is not the shock wave structure and do not show obvious discontinuous boundaries, it is difficult to measure the Hugoniot of ice between HEL and 0.7 GPa. Here we propose a method of Hugoniot estimation of ice between the HEL and 0.7 GPa on the assumption that the main wave in this range consisted of multiple shock waves.

Estimation of Hugoniot :

In order to analyze the Hugoniot of ice, let us consider the multiple shock wave. In the case of multiple shock wave, the jump conditions are written for the n-th shock state centered on the (n-1)-th state:

$V(n)-V(n)/V(n-1) = (u(n)-u(n-1))/(U(n)-u(n-1))$, (1)
$P(n)-P(n-1) = (U(n)-u(n-1))(u(n)-u(n-1))/V(n-1)$, (2)

where P, U, u, and V are stress, shock velocity, particle velocity, and specific volume, respectively. These two equations show the conservation of mass and momentum, respectively, which are referred to as the Hugoniot relations.

Given the experimental data of the stress-time profile (P(n) vs. t(n) curves) in the laboratory frame of reference and the initial conditions (P(0), U(0), V(0), t(0), and l(0), where t and l are the time and the gauge position from the impact surface, respectively), we can calculate the Hugoniot data between 1 and n-th shock states (Us(n), Us(n), and V(n) for the n-th shock state) by Eqs.(1) and (2).

In the case of ice, the previous Hugoniot data between the HEL and 0.7 GPa show that the shock velocity almost decrease with increasing the shock stress. Therefore, we believe that the main shock wave followed by the precursor consists of n-th multiple shock waves. Then we calculate the Hugoniot data between the HEL and 0.7 GPa using the shock wave having the initial peak shock stress lower than 0.7 GPa. This method can be apply an attenuated wave.