ABSTRACT OF THE DISSERTATION

Title: A study on the high precision measurement of thermo-mechanical properties in materials at ultra-high strain rate based on Taylor impact test

(Taylor 衝撃圧縮試験に基づく超高ひずみ速度における材料の熱・力学特性の高精度測定に関する研究)

高　崇

Recently, Voyager 1, a space probe launched by NASA, has arrived in the outer solar system and interstellar space beyond the heliosphere. In such a case, a whirlwind launch velocity over 16.7 km/s is requested to escape from the gravitation of the solar system. Therefore, impact of space debris and meteorite will lead to a grave damage to the spacecraft. Thermo-mechanical behavior of structural materials for a spacecraft at such an expeditious impact velocity must be evaluated in an appropriate experimental method for material design and selection.

Several methods have been established and well-developed for measuring the thermo-mechanical behavior of a material at various deformation speeds. The Taylor impact test, which can achieve a whirlwind impact velocity, is an appropriate method widely used for measuring the strength of a material in nonuniform deformation. Nowadays, it can also measure a stress-strain curve which is crucial to evaluating the deformation behavior of a material. Hence, the Taylor impact test can be selected for evaluating the thermo-mechanical behavior of structural materials adopted in the aerospace industry.

However, the proposed measurement method of a stress-strain curve based on the Taylor impact test does not consider the nonuniform deformation of a specimen. Besides, several times of tests are required to secure a stress-strain curve. Furthermore, an inevitable and obvious temperature rise due to an extremely high-speed impact should be considered for the temperature rise decreases the strength of structural materials in terms of thermal softening. Unfortunately, it is hard to capture the temperature rise of a specimen at such a fast deformation speed.

In this study, a method for measuring the thermo-mechanical behavior of a material at an extremely high deformation speed based on the Taylor impact test is proposed. Validity of the proposed method is discussed from the finite element (FE) simulation firstly. Then, several curves for expressing the thermo-mechanical behavior of a material are assessed by a single test performed after an instrumented

Taylor impact test with an impact force detector, a high-speed camera and a temperature measurement system is established. Chapters of this dissertation are shown as follows:

In **Chapter 1**, the research background, literature review, problem description, objective and structure of the dissertation were introduced.

In **Chapter 2**, preparation before performing the Taylor impact test was shown. Firstly, the feasibility of an infrared detector which will be adopted to measure the temperature rise in the Taylor impact test was deliberated about. Besides, selection of an appropriate model leveraged to express the plastic deformation of a material is essential in terms of the FE simulation used for checking the validity of the proposed method. Therefore, several models were conferred about when compared with the experimental results.

In **Chapter 3**, a measurement method for stress-strain curve based on the Taylor impact test considering the nonuniform deformation was established mathematically. Then, the FE simulation was conducted to check the feasibility of the proposed method. After that, an impact force detector and a high-speed camera were introduced into the apparatus based on the Taylor impact test. A stress-strain curve is obtained from the results given by the impact force detector and the high-speed camera by a single test. Finally, the measured results were verified by a verification experiment.

In **Chapter 4**, a spatial difference method, a theory based on propagation of a stress wave and continuum mechanics, and a calculation method for the strain rate distribution which is also significant to evaluate the thermo-mechanical behavior of a material were established according to the results from **Chapter 3**. Besides, a calculation method for temperature distribution from a temperature rise at a local point and the heat conduction equation was proposed. Then, a temperature measurement system contained a fiber and infrared detector was designed to capture a temperature rise at a local point. Finally, the strain rate distribution and the temperature distribution were attempted to be measured by an experiment performed in the proposed method.

In **Chapter 5**, the problems in **Chapter 2** were reviewed at first. Then, a specimen was newly designed to secure a stress-strain curve with higher accuracy. The dimension for the designed specimen is determined from the FEA result. After that, the determined specimen was introduced into the instrumented Taylor impact test to acquire a stress-strain curve with higher accuracy.

In **Chapter 6**, main conclusions derived from the results of this dissertation were stated. Additionally, recommendations on the future work were put forward.