It is essential to maintain the safety of space structures such as a space station in order to make use of space environments effectively. Especially it is important to develop structural health monitoring techniques that detect the structural damage due to space debris or the structural degradation in real-time, nondestructively and automatically. The objectives of the present research are to improve the reliability and safety of space structures by developing the following two techniques,

1. the technique to identify the impact force acting on space structures in real-time using piezoelectrics, and
2. the technique to monitor of damage of space structures in real-time and automatically.

1. Development of sensors for real-time impact force identification using piezoelectrics embedded in CFRP structures
   
   For CFRP laminated plates with PZT piezoelectric sensors, the relation between the impact force and the strain responses was formulated based on the finite element method, and the
techniques to identify the location and the history of impact force were developed. The impact force identification system is shown in Fig.1, and the example of identified impact force is shown in Fig.2. The identified force history shows a good agreement with measured one. The present system enables more precise identification as compared with existing impact force identification one.

2. Development of modal sensors based on optimal placement of sensors and their application to impact force identification

Precise modal sensors were constructed using optimal placement of several sensors, and were applied to identification of impact force. Fig.3 shows optimal placement using four sensors that can avoid the effect of observation spillover due to higher-order modal displacements. The modal sensors were applied to the impact force identification of aluminum plates impacted by impulse hammer. The identified impact force agreed with an exact force as shown in Fig.4. The present research is very original in the field of the impact force identification.

Fig.3 Optimal placement of sensors

Fig.4 Impact force identification using modal sensors

3. Damage monitoring using piezoelectric sensors

The main damage mode in the CFRP laminated plates due to impact or structural degradation is delamination. Finite element analysis code was developed for CFRP laminated plates, taking into consideration a delamination and piezoelectric sensors. Through numerical computation using the present code, it was shown that a delamination in CFRP laminates can be detected precisely by the responses of PVDF sensors.

The present techniques shown in 1-3 were applied to a simple plate structure, but they can also be applied easily to more complicated structures such as space structures.

9. Publication List

http://www.ssl.mech.tohoku.ac.jp