DEPLOYMENT ANLAYSIS OF SOLAR ARRAY SYSTEM THROUGH FLEXIBLE MULTI-BODY DYNAMIC APPROACH

Jin Yeon CHO [1], Sun Young KIM [1] and Min Hwan Oh[1]

1) *Department of Aerospace Engineering, Inha University, Incheon 402-751, KOREA*
2) *Department of Civil Engineering, Shilla University, Busan 617-736, KOREA*

Corresponding Author: Jin Yeon CHO, cjy@inha.ac.kr

ABSTRACT

Over the years, considerable research efforts have been made to reduce the weight of spacecraft structures because of its astronomical launching cost. As a result, flexible structures are increasingly utilized in spacecraft structures such as satellite. Of these, a solar array system is one of the most flexible structures in spacecraft structures. Usually, the solar array system is stowed in folded shape when the spacecraft is launched, and it is deployed after entering into orbit. Since the solar array system provides most of the power required in spacecrafts for their mission, the failure in deployment of solar array system directly leads to mission failure of spacecrafts. Therefore, reliable deployment analysis, which can take into account the flexibility of solar array system appropriately, is indispensable for design of solar array system.

However, rigid body dynamic approach or mode based approach, which are not fully consider the flexibility of structures, are customarily adopted in industries, and the flexible multi-body dynamic approach is rarely utilized in spite of its advantage in dealing with flexibility of structures. Based on the reason, the flexible multi-body dynamic approach is fully adopted for design of solar array system in this work. In deployment analysis of satellite solar array system, the explicit flexible multi-body dynamic analysis module in commercial software ABAQUS^{TM} is utilized, and some part of analysis results are compared with those obtained from the rigid multi-body dynamic analysis. From the results, it is observed that the flexible multi-body dynamic approach is highly recommendable for design of flexible solar array systems.

EQUATION OF MOTION OF FLEXIBLE MULTI-BODY DYNAMIC SYSTEM

Equation of motion of general 3 dimensional flexible multi-body system can be obtained through the following weak form [1].

$$\int_\Omega \delta u_i \rho \ddot{u}_i d\Omega + \int_\Omega \delta u_{i,j} \sigma_{ij} d\Omega = \int_\Omega \delta u_i f_i d\Omega + \int_{\partial\Omega_t} \delta u_i \bar{t}_i d\Gamma + \int_{\partial\Omega_c} \delta u_i \frac{\partial \phi_k}{\partial u_i} \lambda_k d\Gamma + \int_{\partial\Omega_c} \delta\lambda_k \phi_k d\Gamma, \ \forall \delta u_i, \delta\lambda_k \tag{1}$$

where integral domain Ω is the union of domains of each body, and $\phi_k (1 \le k \le \text{no. of constraints})$ denote the constraint conditions such as joint. It is noted that the constraint can be various forms according to the constraint. By approximation of unknown

variables through finite element shape function, one can obtains the equation of motion (2) which is differential algebraic equation (DAE) [2].

$$\begin{aligned} \mathbf{M}\ddot{\mathbf{q}} + \mathbf{p}(\mathbf{q}) - \mathbf{B}^T\boldsymbol{\lambda} &= \mathbf{0} \\ -\boldsymbol{\Phi}(\mathbf{q}) &= \mathbf{0} \end{aligned} \tag{2}$$

DESIGN OF SOLAR ARRAY SYSTEM

Through the aforementioned flexible multi-body dynamic approach, deployment behavior is analyzed. In deployment analysis of solar array system, the flexible multi-body dynamic analysis module in commercial software ABAQUS^{TM} is utilized along with explicit time integration scheme. In terms of deployment time, it is observed that the flexible multi-body dynamic approach gives the results similar to the rigid body dynamic analysis. However, one cannot obtain the local flexible behaviors of solar array system which is crucial in structural design to prevent the failure. Those behaviors can be fully considered only by flexible multi-body dynamic approach. Fig. 1 shows that the excessive deformation, which may lead to material failure, occurs in the first design. Based on the results, we change the yoke configuration to suppress the excessive deformation. In Fig. 2, the deployment analysis result for the redesigned solar array system is presented. One can observe that the excessive deformation can be effectively suppressed in redesigned solar array system. From the results, one can confirm that the flexible multi-body dynamic methodology is very useful in design of modern solar array systems.

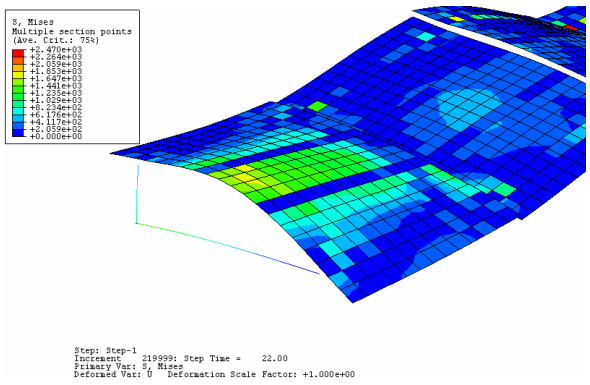

Figure 1. Deformed shape(original system)

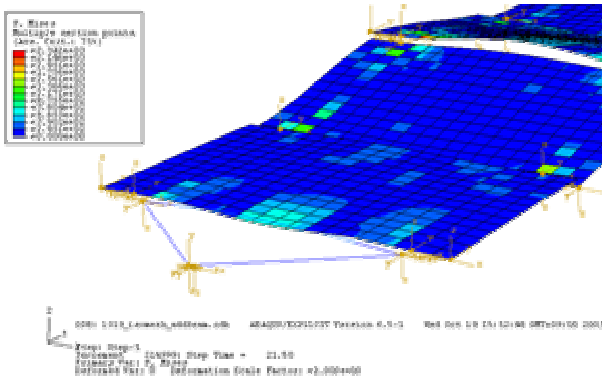

Figure 2. Deformed shape(redesigned system)

ACKNOWLEDGEMENT

Authors would like to acknowledge the financial support from the Korean Air under the Aerospace Technology Development Project of the Ministry of Commerce, Industry and Energy.

REFERENCES

1. Geradin, M., and Cardina, A., *Flexible Multibody Dynamics*, John Wiley & Sons, Baffins Lane, Chichester, 2001.
2. Haug, H., *Intermediate Dynamics*, Prentice-Hall, Engelwood Cliffs, NJ, 1992.