EFFICIENT HEAT ENERGY MANAGEMENT OF AEROSPACE STRUCTURES VIA HEAT-DIRECTED COMPOSITE MATERIALS

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INTRODUCTION

In the aerospace applications, the efficient consumption of the limited amount of energy on the bored is very important for the design requirements (e.g. weight, cost, etc.) and for the environment. Therefore, maximizing thermal efficiency of the heat transfer applications is one of the main keys to achieving effective energy utilization, which includes reducing global warming, and ultimately managing the consumption of energy.

ABSTRACT

Recently, increasing demands for smarter and smaller products calls for the development of multifunctional composites. These materials are used not only as structural materials but also satisfy the needs for additional functionalities such as thermal, electrical, magnetic, optical, chemical, biological, etc.

Therefore in JAXA, we have been introduced novel multifunctional composite materials can help with both sides of the equation of consumption of energy and environment. These composites have additional thermal functionality, called heat-directed property. This heat-directed capability can conduct the majority of the transferred heat by conduction to the preferred area or direction of the thermal structure as shown in Figure 1. This distinctive property can be attained by varying the in-plane thermal conductivity of the composites.

![Fig. 1: (a) Concept of heat transfer in traditional materials; and (b) Concept of heat transfer in the suggested heat-directed materials](image)

Two novel techniques were adopted to fabricate continuously woven carbon fiber reinforced polymer matrix, CFRP, and unidirectional carbon/carbon, C/C, heat-directed composites. In the first technique, changing the in-plane thermal conductivity of the composites materials functionally was achieved by dispersing highly heat-conductive materials such as carbon nanotubes (CNTs) throughout the matrix functionally. While in the second technique,
changing the in-plane thermal conductivity of the material functionally was achieved by using hybrid carbon fibers (Pitch-based and PAN-based carbon fibers with thermal conductivity of 320 and 6.3 W/mk, respectively) in the same prepreg of the C/C composites.

These composites have been examined experimentally by using infrared system and numerically by finite element method. The in-situ full-field infrared measurements and finite element analysis of the designed composites showed that the heat transfer direction can be substantially controlled in both composites as shown in Figure 2 and 3. These experimental results and FEM simulations suggested that the exceptional heat-directed property can play a significant performance improvement in heat transfer process along the in-plane of the materials and decreasing the thermal stresses of the structures as well as helping to decrease the heating up of the Earth, global warming, due to the escaped heat of many engineering applications.

Fig. 2: Full-field infrared observations of temperature distribution of (a) heat-directed CFRP composites using functionally dispersed carbon nanotubes through the matrix (b) heat-directed carbon/carbon composites using hybrid Pitch/PAN carbon fibers.

Fig. 3: The heat transfer propagation of heat-directed carbon/carbon composites using hybrid Pitch/PAN carbon fibers within 800 seconds.

Such composite systems can be promising candidates for heat transfer applications especially when the efficient consumption of the limited amount of energy and the light weight are required. For example, the undesirable heat energy such as the heat loss in the heat exchangers not only can be recovered by using the heat-directed composites but also can make the system doesn’t need some additional requirements (e.g. cooling systems) to recover the resulted effects of this energy loss. These composites also can be used as semi-passive or active thermal protection systems of re-entry space transportation vehicles without need to working fluid or coolant flow.