Development of Safe, Environmentally Friendly Airplane Seat Cushions

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Abstract

All Nippon Airways Co., Ltd. (ANA), Osaka Gas Chemical Co., Ltd. (OGC), and All Nippon Airways Trading Co., Ltd. (ANATC) jointly developed an advanced airplane seat cushion, which is fabricated with a carbon fiber, at the first in the world. The carbon fiber cushion has many beneficial features as a seat cushion in the airplane interior. ANA starts installing the cushions on our fleet.
ANA believes that this advanced seat cushion satisfies beyond the airworthiness requirements and would be the greatest breakthrough for a future technology of the airplane interior.

1 Introduction

Many airlines are constantly maintaining an airplane to satisfy their customer needs.
ANA has been jointly developing the new technology of advanced seat cushion with one of domestic manufacturers so called OGC. Our developed carbon fiber seat cushion has many beneficial features for ANA needs. ANA starts installing them on their fleet. This paper outlines our activities.

2 Airplane Seat Cushion

Airplane seat cushions are especially required no flammable, durability and lightweight. Today, the polyurethane foam is widely used as a seat cushion in the airplane interior because of its appropriate cushion performance, simple procurement process with reasonable cost. The feature of this material, such as incombustibility complies the airworthiness requirements. However, the polyurethane itself is not a flameproof material. Therefore, to meet these aviation regulations, it should be processed a flameproof finish or covered with a fire-blocking layer. ANA believes that many airlines are more beneficial if the feature of the cushion material, such as low combustibility, durability, and less-weight would be improved for inducing safe and efficient operations.

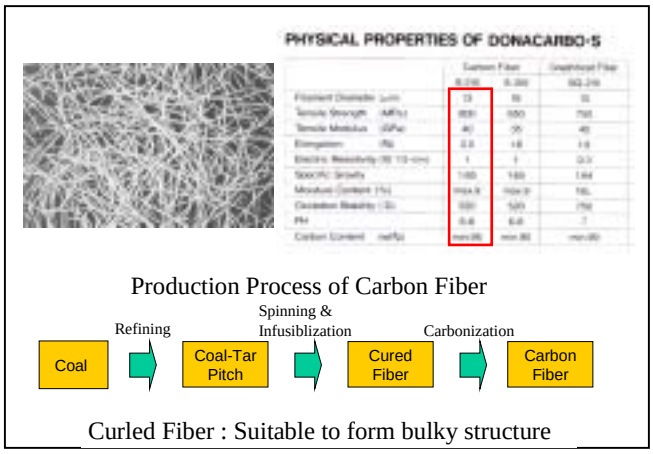
On the other hand, ANA replaces all seat cushions at every five years cycle for passenger comfort. Used cushions are fully disposed as an industrial waste and would bring an environmental hazard to the earth.
ANA is concerned about environment presentation, and introduces this program as a solution.

3 Carbon Fiber and Carbon Fiber Cushion

3.1 Carbon Fiber

Pitch-based carbon fibers, 13 μm in diameter each, manufactured by Donac Co., Ltd., a 100% subsidiary of OGC are used for the cushions. This type has characteristics not provided by other types and each piece of fiber is curled. It is suitable as a cushion material since it allows easy molding with excellent cushioning performance. Fig. 1 shows the fiber production process.

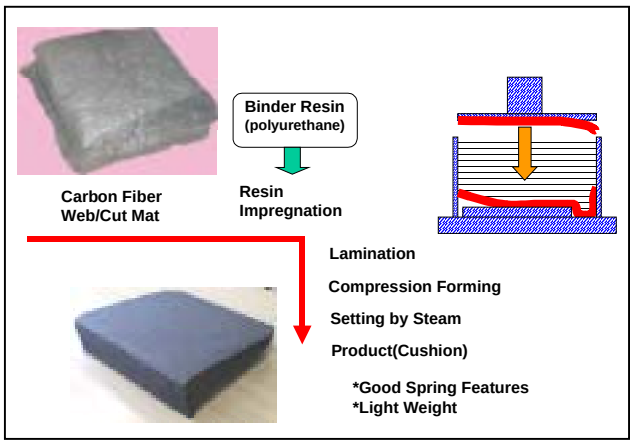
Fig. 1 Production Process – Carbon Fiber



3.2 Carbon Fiber Cushion

To manufacture the carbon fiber cushion, a mass of fibers are formed into a mat shape and are molded after impregnation with polyurethane as the binder in a wire netting mold by heating with hot steam. The binder is then set to form the carbon fiber cushion. (See Fig. 2.)

Fig. 2 Production Process – Carbon Fiber Cushion



4 Development of Airplane Carbon Fiber Cushion

Through the examination, it was confirmed that the carbon fiber cushion has following beneficial features as a seat cushion in the airplane interior. ANA, OGC and ANATC start developing the cushion for ANA fleet.

<Feature of Carbon Fiber Cushion>

- Less combustible
- Less toxic gas
- Less weight
- Better ventilation
- 100% recyclable
- High durability against ultraviolet rays and moisture

The cushion on an airplane varies with the seat type. As the first, we start developing the seat cushion for the economy class seats on the Boeing 767 because whole cushion replacement cycle is upcoming.
The seat cushion consists of the bottom portion and the backrest portion. We selected the bottom portion that dominates the seating comfort so as to confirm the possibility of developing a more satisfactory seat cushion.
In the development, therefore, we tested the seating comfort in further to examining excellent properties of the carbon fiber cushion

4.1 Less combustible and toxic gas

The aviation regulation requires very strict fire resistance for the materials to be used civil airplane interior. The requirements are much stricter for products such as seat cushions that account for much volume in total.

Fig. 3 shows the status of oil burner test as one of flammability tests for the cushion. In the test, the specified powerful flame is applied for two minutes to confirm that both the combustion length and weight loss of the cushion are less than the required limits.
The fire resistance requirements are specified so as to ensure sufficient time for passengers and crewmembers to escape by preventing sudden spreading of the flame in case a fire starts.
A slight amount of polyurethane is used as the binder for molding the carbon fiber mat into a cushion as stated before. Since the main composed material is carbon fibers, an excellent fire resistance is confirmed by the flammability test.

In addition, carbon fibers generate an extremely small amount of toxic gas, safety against fire is improved greatly.

Fig. 3 Cushion Flammability Test

4.2 Less weight and better ventilation

In comparison, the carbon fiber cushion has advanced feature in reducing weight over the polyurethane cushions.
Weight reduction leads fuel economy as a result, save cost and planet, environmentally.
The unit weight of the bottom portion cushion developed for Boeing 767 is about 800 g.
The current cushion used on the airplane is the most simple one in which the polyurethane form is covered with flameproof material such as fire-blocking layer, and is the lightest weight among seats using in ANA.
The weight, therefore, is not much different from the carbon fiber cushion weight, resulting in no fuel reduction effect.
However, because of the advanced flameproof feature so that the fire-blocking layer is not required.

Table 1 shows estimated fuel reduction for major ANA fleet if the current polyurethane seat cushions (bottom & backrest) are replaced by carbon fiber cushions.

Most seat cushions ANA uses in economic class are weigh between 1,100 and 1,300 g. In the case of Boeing 747-400D having a large capacity, so does weight reduction per airplane is predicted to be about 450 kg at most.
The calculation is based on the operation records (number of seats, number of flights, and flying distance) in fiscal 2001. With regard to the two models (the 747-400 and the 777) operated by ANA, the fuel reduction will amount to about 875 tons per year.

Table-1 Fuel saving

Aircraft	Route	Weight Reduction		Fuel Save
		(g/Seat)	(Kg/Plane)	(Kg/Year)
B747-400	Domestic	500	170	3,000
	International	500	170	330,000
B747-400D	Domestic	800	450	290,000
	International	800	450	22,000
B777-200	Domestic	700	260	115,000
	International	700	200	15,000
B777-200ER	Domestic	700	160	80
	International	700	160	40,000
B777-300	Domestic	600	290	60,000
Total				875,000
A320	Domestic	500	88	58,000

Since the carbon fiber cushions also feature excellent ventilation, retention of stuffing and odor due to sweat is unlikely to occur, resulting in improved comfortability.

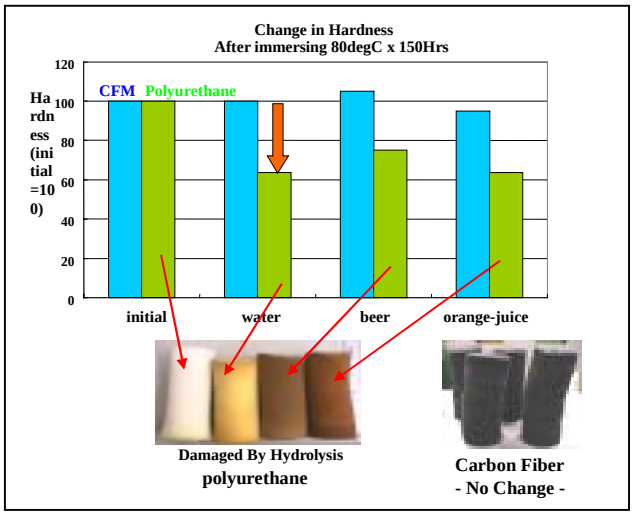
4.3 Durability

One of the weaknesses of polyurethane cushion causes a degradation due to ultraviolet rays and moisture. However, carbon fiber cushion has better strength.

Fig. 4 compares the results of accelerated aging test using water, beer, and orange juice, which are frequently used for in-flight service.
While no degradation is seen in the inorganic carbon fiber cushion, conspicuous softening is seen in the urethane cushion. Also in the case of the urethane cushion, ragged degradation due to the influence of ultraviolet rays is frequently experienced.

To check the durability against repeated stress, a load of 77 kg is applied 150,000 times. The permanent set and loss of hardness are measured every 50,000 times of loading. As the result, both the permanent set and loss of hardness are slight to prove excellent recovery from compression.
As stated above we have confirmed the excellent durability of the carbon fiber cushion.

Fig. 4 Degradation Test

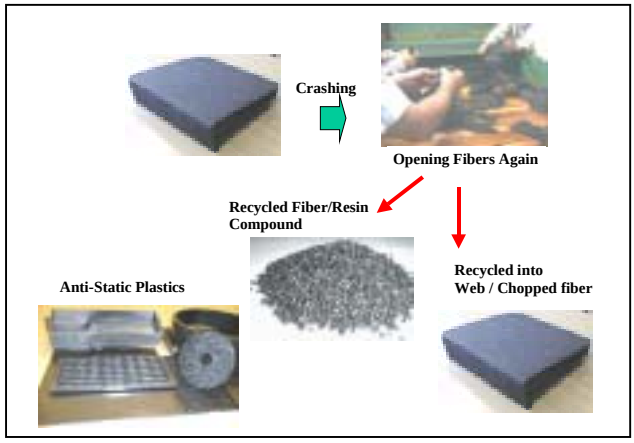


4.4 100% Recyclable

ANA replaces seat cushions of all airplane models at every five years cycle.
The removed polyurethane cushions are fully disposed as industrial wastes. Two to three 4-ton trucks are used to transport removed bottom and backrest cushions from one airplane. Since the ANA group operates about 200 airplanes, replacement of these cushions every five years means disposal of old cushions corresponding to about one hundred 4-ton transporting trucks each year.

In case of the carbon fiber cushions, unbinding the molded body allows reuse of carbon fibers as the cushion material. When combined with resin or mortar, 100% recycling in the form of a semiconductor manufacturing or wall material is possible. The removed cushions, therefore, are fully transported to OGC for the recycle. (See Fig. 5.)

Fig. 5 Recycling Features

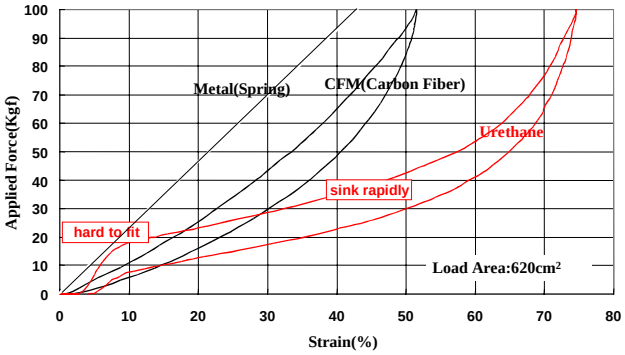


4.5 Seating comfort of cushions

Providing comfortable seats is one of important services in airline business.
Cushion hardness, shape and raw materials are conceivable factors that influence seating comfort. To attain better seating comfort, many cushions different in carbon fiber density and shape were examined before finalizing the product.

We have summarized feedback from employees who test the comfort and we finalized production.
To examine general properties related to the seating comfort of the carbon fiber cushions, the stress-strain relationship of the carbon fiber cushion is measured and compared with that of the polyurethane cushion having the same density.
As shown in Fig. 6, the strain varies more linearly as compared with the polyurethane cushion involving great strain for the initial load (greater sinking upon seating), thereby showing similarity with the spring cushion as an ideal cushion.

Fig. 6 Stress-Strain Curve



5 Installation to Airplanes

The prototype seat cushion for Boeing 767 after development completion is tested at the seat manufacturer (Tenryu Kogyo) according to the aviation regulations.
The local regulatory agency, the JCAB releases certification in early July, 2003. In July 2003, ANA starts introducing this product into Boeing 767 airplanes. The developed cushions will replace the existing polyurethane cushions, and to be installed at scheduled replacement cycle. ANA completed fiber cushion installation into five airplanes so far at March 2004.

6 Future Plan and Remaining Task

Since carbon fiber cushions have excellent properties matching the airline needs, it is considered very promising as the next-generation airplane seat cushions.
ANA plans to replace cushions for A320 from summer 2004 as well. The carbon fiber cushions are being developed for the both bottom and backrest of that airplane model. This time, extremely price reduction of the cushions is also expected.

After certain period is over, ANA will remove some cushions as a sample testing and evaluate durability whether the five years replacement cycle can be extended. And the evaluation result will be used for further improvement.

ANA plans to introduce the advanced cushion into other fleet in near future.