AD-A095 700   FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OH   F/G 11/4
SPACECRAFT: NEW MATERIALS,(U)
JAN 81 Z GONG-LIANG
UNCLASSIFIED   FTD-ID(RS)T-1232-80   NL

1 OF 1
AD
A095 700

END
DATE
FILMED
3-81
DTIC

AD A095 ___ 0

FTD-ID(RS)T-1232-80

FOREIGN TECHNOLOGY DIVISION

SPACECRAFT: NEW MATERIALS

by

Zhou Gong-Liang

Approved for public release;
distribution unlimited.

FTD -ID(RS)T-1232-80

EDITED TRANSLATION

FTD-ID(RS)T-1232-80 9 Jan ~~uary 1~~981

MICROFICHE NR: FTD-80-C-001272

SPACECRAFT: NEW MATERIALS

By Zhou Gong-Liang

English pages: 10

Source: Hang K'ung Chih Shih ~~Nr. 11, 1979,~~

Country of origin: China
Translated by: SCITRAN
F33657-78-D-0619
Requester: FTD/TQTD
Approved for public release; distribution unlimited.

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT. STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE FOREIGN TECHNOLOGY DIVISION.	PREPARED BY: TRANSLATION DIVISION FOREIGN TECHNOLOGY DIVISION WP-AFB, OHIO.

141

SPACECRAFT: NEW MATERIALS

Zhou Gong-Liang

As spacecraft leave Earth and enter space, they must pass stern tests. Since the materials used in these spacecraft must be able to meet the requirements of their external environment as well as protect and maintain a stable operating environment within themselves, the development of these spacecraft is going to cause new progress in the scientific development of materials.

Due to the continuous development of science and technology of spacecraft, spacecraft are not only required to be reliable and safe during the process of launching, flight and return through the atmosphere, but also to be light, have a large effective interior space and carry heavy payloads; moreover, they must be multi-purpose vehicles. While satisfying these requirements, spacecraft must be able to cope with very complicated and difficult environments in space. For example, these spacecraft must undergo the fierce vibrations produced by the thrust from the engines of rockets that can lift heavy payloads; moreover, during flight they must deal with various kinds of random loads, ion flow shocks, high vacuums and extreme changes in temperature. When they re-enter Earth's atmosphere, they must withstand 40-100 atmospheres of pressure and 50-100 kilocalories/m^2 sec of heat flow (the surface of the spacecraft may reach a temperature of 1000-2000°C) as well as ion flow and high speed air flow erosion, corrosion, etc.

How can it be possible to make spacecraft perform reliably in such a hostile environment? One must begin by giving some consideration to materials. Materials for the structure of the main body must have small specific gravities, high moduli of elasticity, low natural frequencies, small coefficients of expansion and resistance to dielectric corrosion and radiation as well as a strong resistance to vaporization in high vacuums. The exhaust jets of the combustion chamber of the rocket motors must be made of materials with a high resistance to temperature and heat stress. Moreover, during re-entry into the Earth's atmosphere, components of the spacecraft that are exposed to extremely high heat (such as the nose cone, etc.) must certainly be composed of materials with high strengths and high resistance to heat. At the same time, it is still necessary that these materials possess the characteristics of high temperature of combustion corrosion, low rates of combustion corrosion and low heat stress.

New man-made satellites have already begun to use structural materials made with beryllium. Structural materials for aircraft and spacecraft have depended heavily on the modern development of fiber-reinforced materials. The combustion chambers and exhaust jets of liquid and gaseous rocket engines already employ carbon based materials and tungsten alloys. The re-entry surfaces and nose cones of spacecraft already employ carbon-based materials and various components of spacecraft are presently being manufactured with alloys of beryllium.

The development of new materials for spacecraft has been very rapid and there are many types of these new materials; below we give a simple introduction to a few types of the most important of these materials.

COMPOSITE FIBER-REINFORCED MATERIALS

The composite fiber-reinforced materials currently in use can be divided into two types: metallic and non-metallic. There are two types of commonly used fibers: Boron fibers and carbon (or graphite) fibers. The ordinary melting point of boron fibers is 2050°C; its specific gravity is $2.63 g/cm^3$; tensile strength is $340\ kg/mm^2$; its elasticity modulus is $40{,}000\ kg/mm^2$. The strength of graphite fibers can reach 200-$300\ kg/mm^2$; their coefficient of elasticity is $20{,}000$-$30{,}000\ kg/mm^2$.

The excellent capabilities of modern composite fiber-reinforced materials are achieved by taking the kinds of high capability fibers discussed above and adding them to metallic basic materials that are electrical conductors, have high heats of conduction and low permeable vaporizations, or by adding them to plastic materials of a certain strength which have high heat resistance, good technical characteristics and low specific gravity; fibers are joined to these basic materials by "braiding" them into the basic materials. There are two types of metallic composite materials that have already been produced successfully and are beginning to be used; they are the boron/aluminum type and the boron/titanium type. Among the non-metallic composite materials are the carbon resin/polyamide resin type, the carbon/carbon type, etc.

The specific gravities of high tensile strength aluminum alloy and boron/aluminum are quite close; however, the coefficient of elasticity of boron/aluminum fibers along their length is three times that of aluminum alloy and the strength of the boron/aluminum fibers is twice that of aluminum alloy. If composite materials are used to manufacture structural components for spacecraft, the weight of the spacecraft concerned can be cut by 30-40%.

The importance of lightening the spacecraft is very great. Taking the Apollo command module as an example, if it had been possible to lighten the craft by 30%, then it would have been possible

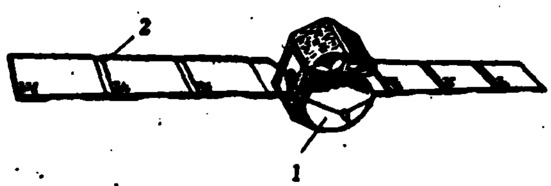


Figure 1. Components of the European communications satellite that use composite materials
1--parabolic antenna; 2--solar battery panels

to carry another 907 kg of instrumentation or provide another several weeks of supplies for the crew. Every kg that can be saved in the weight of the lifting rocket allows a 30 kg reduction in the launch weight of the system.

Now, why do fibers as fine as a spider's web have such particularly high strengths? This is because of the fact that in extremely fine fiber materials there are fewer gaps and impurities than there are in rod-type materials; for example, the strength of a filament of soft iron with a diameter of 0.002 mm is 60 times that of a rod of the same material. Graphite filaments use a type of polyaldehyde crystal fiber to increase their tensile strength to a certain level. Then these fibers are first subjected to thermal oxidation in air at 200-300°C and then carbonized at 1000°C. Finally, the fibers undergo graphite crystallization at 3000°C in an atmosphere of inert gases. The method for manufacturing boron filaments is to first take boron trichloride and put it through a high temperature reduction or refining process. After the pure boron is separated, it settles onto a fine tungsten wire; then the layer of silicon carbide, etc., on the settled material is formed into boron filament.

The technology for making composite materials out of resin base materials and carbon filaments is relatively simple. Moreover, the technology for making composite materials out of titanium and other such metals or alloys in combination with boron fibers cannot be called really complicated. Using the discoveries made by researchers, it is possible to employ the plasma jet application method, the electrolytic sedimentation method, the continuous casting method, etc.

Graphite/polyethylene composite materials have already been employed in the antenna system and Earth observation equipment of the applied technology satellite "AFS"F of the American space flight authorities. Its antenna framework is formed from eight lengths of HM-S graphite/polyethylene tubing; such a tube, weighing 3.6 kg, can accept a compression load of nine tons; this performance is achieved even though the tubing is 50% lighter than similar high-strength frameworks. In those spacecraft the United States is currently producing experimentally, the frames of the central fuselage and reinforcing structures are all being made from boron/titanium composite materials (Figure 2). The solar panels and the parabolic antenna of the European communications satellite were both made employing carbon fiber composite materials (Figure 1).

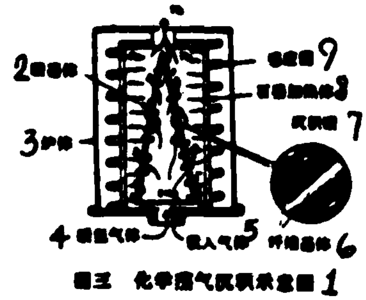


Figure 3

1--chemical vapor sedimentation diagram; 2--main carbon body; 3--furnace body; 4--hydrocarbon gas; 5--charging gas; 6--fiber body; 7--carbon sedimentation; 8--graphite heating body; 9--induction coil

Carbon/carbon composite materials use carbon fibers, graphite fibers or a plaiting of the two together to act as the strengthening agent, and use carbonized or graphitized resin in conjunction with a chemical vapor sedimentation process (Figure 3) to produce the basic material to be strengthened. This process produces this special type of composite material.

There are many ways of strengthening this type of material: For example, the long fiber entwining method which uses colleterial fibers or a type of polyethylene crystal fibers as well as wool in order to make felt which is then carbonized to become carbon felt; carbon fibers are then woven into the fabric, etc.

Fibers can go through the strengthening processes described above and be given the external shape of any desired part; after that, a chemical vapor sedimentation process can be used to make carbon/carbon composite materials.

These types of materials have extremely good mechanical properties, thermophysical properties and corrosion properties. Their usual specific gravity is 1.6 g/cm^3; however, their tensile strength is only 400-1000 kg/cm^2 and even at approximately 260°C, it does not go down; finally, coefficients of tensile elasticity are high, reaching $3x10^5$-$7x10^5$ kg/cm^2. The specific heat of these types of materials are in the range of 2.5-3 calories/g ·°C and increase with increases in temperature; coefficients of expansion are only $2\text{-}7x10^{-6}$; these are one-fifth to one-tenth those of metallic materials and this is very useful in the reduction of heat stress. The corrosion heat of these materials can reach approximately 10,000 calories/g; however, the corrosion rate drops to about 0.2mm/sec. The weak point of these materials is their high coefficients of thermal conductivity; although these are small compared to those of lump graphite, it is illogical to call these heat resistant materials. In order to deal with this problem, different people have created quite a few solutions; for example, in the direction of heat conduction of the tri-directional composite material, a small number of quartz fibers with a low coefficient of thermal conduction can be substituted for the carbon fibers and the thermal conductivity of the material can be lowered to approximately $1.89x10^{-8}$.

Because carbon/carbon composite materials have these types of striking properties, the United States already uses them in the construction of spacecraft re-entry nose cones, and their use has been a success. In spacecraft currently in developmental production, these materials are being used in their forward sections, on the leading edges of their wings and in other such components.

HIGH MELTING POINT ALLOYS

High melting point alloys are formed by taking metals with high melting points, such as tungsten, molybdenum, tantalum and niobium and using them as the basic materials. Then various elements are added which strengthen the basic materials, give them higher resistance to oxidation and improve their technical properties. At present, there are already many types of titanium, molybdenum, tantalum and

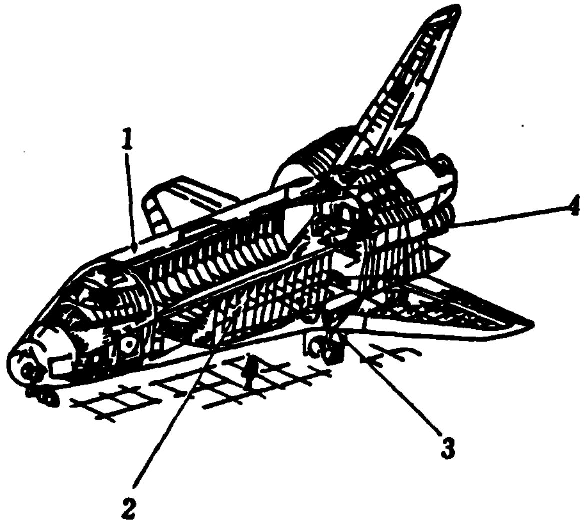


Figure 2. Applications of composite materials in the space shuttle.

1--cargo doors use carbon/polyethylene composite materials; 2--the center section of the fuselage framework uses boron/aluminum composite materials; 3--landing gear storage compartment uses carbon/polyethylene composite materials; 4--thruster structures use carbon/polyethylene composite materials

niobium alloys which are used in the construction of aircraft, missiles and spacecraft; however, as far as spacecraft are concerned and, more particularly, in the case of flight spacecraft, the material with the greatest future for development is still alloys of niobium. The melting point of niobium is 2500°C and it can be used in the temperature range of 1300-1600°C; compared to the presently used high temperature nickel alloys, this represents an increase in usable temperature range of approximately 300-600°C. The specific gravity of niobium is quite close to that of structural steel, that is, 8.5 g/cm^3, and its high temperature strength, its low temperature plasticity and its room temperature chemical stability are all very good. When elements like hafnium and titanium are added, it is possible to obtain strengthening results. If chromium, aluminum, silicon and titanium are added, it is possible to achieve the highest possible resistance to oxidation; however, it is easy to cause the alloy to go brittle and lower its strength.

The American McDonnell-Douglas Aerospace Company, which is currently carrying on test production of their space shuttle, has already used niobium alloys in the leading edges of its wings and control surfaces; the operational temperature for these areas is 1093°C (Figure 4).

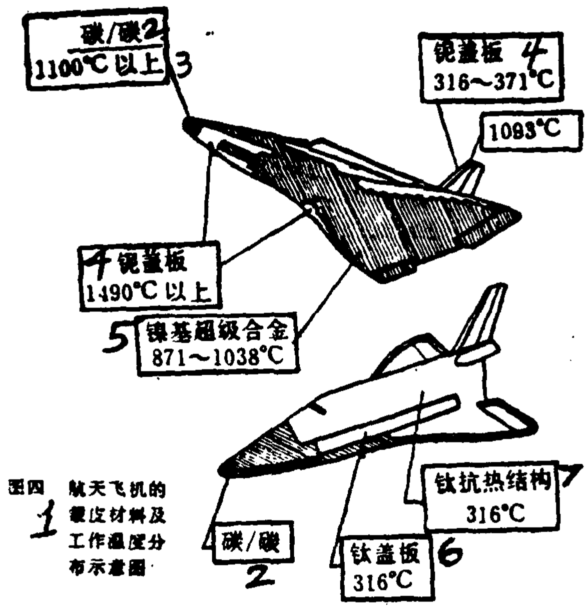
The drawback to niobium alloys is that under high temperatures they tend to lose their anti-oxidation capabilities and cannot be used for long periods of time. In order to increase the anti-oxidation capabilities of these alloys, a great deal of research was carried out, and it was learned that a relatively effective method for doing this is the application of a protective layer to the alloy. Silicides make a rather good protective layer and, after their application, the niobium alloys can withstand 200-800 hours at 1300°C and 200 hours at 1400°C. However, this type of material still has inadequate resistance to air flow blast and it tends to become brittle after the application of the protective coating; these problems require further research.

Besides this, due to the fact that pure metallic beryllium has an extremely high coefficient of elasticity (30,000 kg/mm^2 which is 6-7 times that of magnesium), a small specific gravity (1.85 g/cm^3 which is about the same as that of magnesium), a high melting point (1285°C which is twice that of magnesium) and relatively high strength (50-60 kg/mm^2) it is also an important structural material in spacecraft. Because parts made from beryllium have stable dimensions and excellent thermal conductivity, it is also an ideal material for parts of precision instruments in spacecraft. One type of satellite put up by the Europeans uses a beryllium structure made by a plasma body method. The use of beryllium instrument components has already achieved wide applications. The drawbacks of beryllium are that it is very expensive and very brittle; only if one has extremely pure beryllium can he be assured of plasticity. Beryllium vapors are poisonous and this creates technical problems. All these are problems that require more research in order to solve.

FUTURE OF DEVELOPMENT

From the end of the 1950's on into the 1970's, space flight technology has undergone tremendous development; however, viewed from a long-term perspective, space technology is in nothing but an initial stage. Because man has just left Earth and has only just had a few direct contacts with the moon, his knowledge of the other celestial bodies is quite inadequate. Mankind must use space for its own benefit and the hope that it may establish relations with worlds in space which can support high-level creatures is not outside the realm of possibility. Because of this, the work of studying new materials for spacecraft such as composite materials, high temperature alloys, etc., is in its infancy. It can be estimated that, in the period from 1980-2000, there will be new breakthroughs in space technology. Besides the use of spacecraft, men will set up large scale space stations. In order to solve energy problems, it will be necessary to set up large diameter solar power satellites. There are those who estimate that, because of the rapid development of communications, the chance of discovering high level creatures on other celestial bodies will have reached 50% by the year 2000; emigration to these might become a scheduled occurrence Because of this, the foundation of making spacecraft--the science of materials--must experience equally great developments. It is possible to discover fiber-reinforced composite materials, whether with metal bases or polymer bases, which can reach application temperatures of 550°C, or new types of alloy materials which can operate for extended periods at 1200°C as well as beryllium alloys with small specific gravities, high strength and high coefficients of elasticity, etc.

CAPTIONS AND LAYOUT: Wen Cheng-cheng



图四 航天飞机的蒙皮材料及工作温度分布示意图 1

Figure 4

1--illustration of operational heat distribution and skin construction of space shuttle; 2--carbon/carbon; 3--1100°C and over; 4--niobium covering panels; 5--nickel base super-alloy; 6--titanium covering panels; 7--heat resistant titanium structure

LMED

8