Mechanical Behavior of PBO Fiber Used for Lunar Soil Sampler

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Abstract. The stability of the mechanical properties of the materials used for lunar soil sampler at different temperatures is one of the key factors to ensure the success of the lunar sampling task. In this paper, two kinds of poly(pphenylene-2,6-benzobisoxazole) (PBO) fiber fabric used for lunar soil sampler, flexible tube and wireline, are tested for mechanical properties. The results show that the mechanical properties of the PBO flexible tube and wireline raised 8.3% and 5.7% respectively in -194°C environment comparing with the room temperature of 25°C. When the temperature rises to 300°C, the deviation is -38.6% and -46.4% respectively.

1. Introduction
PBO fiber perform excellently in specific strength, high specific modulus and temperature tolerance, thus it is considered as a new generation of composite materials in aerospace [1]. The physical and chemical properties of PBO fiber keep stable in the -200°C ~ +300°C temperature range, thermal decomposition temperature up to 650°C, with the highest thermal stability in synthetic fiber[2-4]. A diameter of 1mm PBO filament can lift 450kg of weight, that the tensile strength of the fiber is more than 10 times of steel fiber. High modulus PBO fiber have a dimensional stability that the plastic deformation does not exceed 0.03% at 50% fracture load lasting 100h[5-7]. At the same time, the creep resistance of PBO fibers under 5% fracture load is twice that of paraaramid fiber under the same conditions. PBO fiber also has a negative linear expansion coefficient, with a thermal expansion coefficient of -3.0 × 10⁻⁶[8,9]. Its size will not change due to humidity changes, and the impact of heat and moisture is minimal. The friction coefficient of PBO fiber and stainless steel is 0.2, and it is good wearable material. The softness of PBO fiber is excellent, similar to polyester fabric. This characteristic is extremely beneficial for textile weaving process[10]. The flexible tube and wireline used for lunar soil sampler are woven with PBO fibers, as shown in Figure 1. The designed maximum load capacity is 600N.
2. Experimental design

2.1. Experimental methods
In order to simulate the lunar environment, three sets of comparative tests were carried out on flexible tube and wireline. The sets of flexible tube and wireline are treated for 3 hours at temperature of 300 ℃, -194 ℃ and 25 ℃ respectively. Then they are tested at room temperature on the tensile machine.

2.2. Experimental apparatus and parameters
As shown in Figure 2a, an electronic universal tensile testing machine, with maximum load of 50KN, beam speed range 0.02-500 mm/min, and load accuracy ± 0.5%, can be used in load, displacement, strain three control methods; Figure 2b shows a liquid nitrogen cryostat using liquid nitrogen cooling in the standard atmospheric pressure, and its minimum temperature can reach -195.8 ℃; Figure 2c shows an electric drying oven, that the control temperature ranges in 10-300 ℃.

2.3. Experimental process
Using different special fixture, the initial pre-tension of the flexible tubes are set to 100N and 20N, respectively. The quasi-static loading speed is 10mm/min. The test procedure was repeated three times in each group, as shown in Figure 3.
3. Experimental design

The failure status of the flexible tube and wireline treated at different temperatures is shown in Fig.4. The woven process of the flexible tube is plain weave, warp and weft in crossing form. This kind of weaving is also the most qualitative, that the organizational structure is not easy to change. Therefore, during the process of tensile failure, the development of the warp fracture is broken one yarn by the other until it is completely destroyed. Yet, the wireline is oblique weave, and the warp or weft yarns will overlap each other with two or more yarns. Therefore, the destruction is instantaneous.

a) Flexible tube at room temperature b) Flexible tube at high temperature c) Flexible tube at low temperature d) wireline at room temperature e) wireline at high temperature f) wireline at low temperature

The width of the flexible tube is 23.6 mm and the thickness is 0.6 mm. The stretching curve is shown in Fig.5. It can be seen that the mechanical properties of flexible tube after cryopreservation have increased by 8.3% compared with that under normal temperature. The mechanical properties of flexible tube after high temperature treatment are lower than that of normal temperature, which is -38.6% lower, but still over the design target of 600N.
The width of the wireline is 3 mm and the thickness is 0.5 mm. The stretching curve is shown in Fig.6. It can be seen that, similar to the flexible tube, the mechanical properties of wireline after cryogenic treatment have risen 5.7% compared to that under normal temperature. The wireline mechanical properties decreased significantly after high temperature treatment. The amount of change is -46.4% compared to room temperature conditions, still over the design target of 600N.

Figure.5. Tensile curve of flexible tube at different temperature

Figure.6. Tensile curve of wireline at different temperature

4. Conclusion

PBO fiber has excellent mechanical properties, after the complex weaving process and surface coating treatment process, the PBO finished products can meet the lunar surface conditions under the load requirements. The mechanical properties of PBO products after the high temperature treatment decreased slightly, the decline rate of flexible tube is -38.6% and that of wireline is -46.4%, while the low temperature treatment will enhance its mechanical properties, the rise rate of flexible tube is 8.3% and that of wireline is 5.7%.

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