Compatibility test of a complex film in emiction with additive used in space station

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Abstract. A new nine layer film of liquid tank in China space station is used to store emiction with additive in urine treatment subsystem. It is the main material for storing strongly corrosive medium. There should be no leakage during the storing process. Compatibility of the nine layer film with emiction with additive is very important. In order to test the life of this material, experiment for compatibility test is performed. 1-liter complex film bag made by this film is designed to store the emiction with additive. The compatibility test and mechanical properties test showed that the nine layers complex film has good compatibility with emiction with additive used in in China space station. The height of nine layers film decreases by 5% after 90 days and it decreases by 13.6% after 750 days. Stretching intensity and stretching strain decrease during the storage process, while the elongation at break has no change basically. The nine layers film material offers a new method for the design and application of liquid container in space station.

1. Introduction

In the long-term space flight, the most realistic and economical way of water supply is to realize the recycling of water, that is, the regeneration of wastewater. The regeneration of urine is the most difficult and critical. There are two ways to treat and reuse the urine in space station: one is to treat it separately with a urine processor, and the recycled water is used to flush the urinal, electrolyze oxygen, or enter the water treatment unit with other wastewater for secondary treatment; the other way is to mix the urine with other wastewater, and it is chemical extracted for drinking and sanitation for astronauts. The process for the former is distillation, advanced oxidation and freeze drying, which can remove impurities from urine in the process. There have biological methods for the latter, and the main target pollutant is urea. In the urine treatment subsystem, the long term storage of emiction with additive is very important. A liquid tank for emiction with additive is the key component for this subsystem.

At present, Contingency Water Container (CWC) is the most popular water containers in the international space station. It is mainly used to store water for drinking before the water was consumed [1]. CWC uses Combitherm VPCXX140 as the direct material for storing water. It can make the water doesn’t go bad for several months. Payload Water Reservoir (PWR) is another kind of liquid container which is manufactured by American Fluoroseal [2]. The PWR is developed as a medium size container geared toward payload applications such as plant, insect and animal experiment fluid supply [3]. PWR uses a kind of bladder to store corrosive medium, and this bladder is made from
FEP film. The Rodnik is Russian ground prepared potable water that is periodically launched in the Rodnik tanks of Progress vehicles [4]. Rodnik tanks is manufactured by metal structure and internal film. The metal structure can support higher pressure inside the tank than the CWC container. Designed in Russia also developed a kind of bladder tank to store water for drinking which is EDV [5]. CWC and PWR are convenient to transport in space with micro gravity. The CWC can be folded in a small space. When the water in the CWC is consumed, the CWC tanks can be folded and stored together. Rodnik has cone angle for the metal structure, and the metal part can be stacked together with several same part [6].

Combitherm film is used in CWC, which has good compatibility with drinking water added ionic silver [7-8]. The Combitherm VPCXX-140 film can not be used in the store of high causticity fluids [9]. The melting temperature of FEP is about 400°C, and it is much higher than the melting temperature of PE [10]. Russia develops a kind of material which named PVDF, and it is used in Rodnik and EDV [11-12]. The compatibility between drinking water and PVDF is not good enough for storing for a long time [13-14].

A kind of nine layers complex film has been developed and used in the urine treatment subsystem future China space station. The complex film is used in liquid tank which is shown in Figure 1. The major structure of water tank is mode of aluminium alloy. The complex film is used in the in internal face of the aluminium alloy shell. Alloy is not compatible with emicition with additive. The storage life of emicition with additive is determined by the complex film. The nine layers film is a new material, so material compatibility test should be done before use. An experiment test is designed to test the compatibility of the film with emication with additive. 1L bags which are manufactured by nine layers film are used for long term storage. The thickness and mechanical property are tested with several sampling periods.

![Complex film](image)

**Figure 1.** The complex film is used in liquid tank.

**Table 1.** 9 layer materials of the nine layers film.

| layers | Name of material         | layers | Name of material         |
|--------|--------------------------|--------|--------------------------|
| 1      | MLLDPE                   | 6      | PA Nylon                 |
| 2      | Polyethylene tie layer   | 7      | Adhesive layer           |
| 3      | Adhesive layer           | 8      | Polyethylene tie layer   |
| 4      | PA Nylon                 | 9      | MLLDPE                   |
| 5      | EVOH                     |        |                          |
2. **Components of complex film**

5 different materials are formed of the nine layers film, which are Mao Linear Low Density Polyethylene (MLLDPE), Polyethylene tie layer, Adhesive layer, PA Nylon, Ethylene vinyl alcohol (EVOH). Different materials in each layer are shown in Table 1.

The proportion of MLLDPE is 20%, Polyethylene tie layer is 40%, Adhesive layer is 10%, PA Nylon is 20%, EVOH is 10%.

3. **Property of the complex film**

3.1. **Experimental methods**

The emission with additive for China space station is stored for more than 700 days. For the experimental test, the emission with additive was confected by 24L emission and 240g additive. The additive contains 26.4g analytically pure CrO₃ (concentration is 11%), 107.04g oil of vitriol (98%) and 106.56g distilled water. Then blend the 240g additive with 24L emission, and let them intensive mixing and mix uniformly. Fill 24 1L bags which are manufactued by nine layers film with emission with additive. Put these 1L bags in clean room. Test the property of the complex film with the time according to Table 2.

| No. | 1   | 2   | 3   | 4   | 5   |
|-----|-----|-----|-----|-----|-----|
| Days| 0   | 30  | 60  | 90  | 750 |
| Thickness test | 1   | 1   | 1   | 1   | 1   |
| Mechanical property test | 1   | 1   | 1   | 1   | 1   |

When it reaches the sampling time, emptying the 1L bag and clean the complex film with distilled water. Check the leakage of the 1L bag and whether there has corrosion spot on the bag. For the thickness test, 20 point uniformly distributed in the surface of the bag are chosen for thickness test. The minimum value is the thickness result. Experimental test of thickness is performed according to GB/T6672-2001. Mechanical properties of the complex film are tested according to GB/T1040-2006. Mechanical properties include stretching intensity, stretching strain, longitudinal right angle tear strength, right angle tear strength and stretching intensity of heat-seal.

3.2. **Thickness change**

Thickness test results are shown on Table 3. When the storage process lasts 90 days, the thickness of the complex film reduce by 5%. The corrosion rate of the film is high which reaches 0.12% per day. When it stores more than 30 day, the corrosion rate decreases and it is 0.02% per day. The thickness reduce for 718 days is 14.4%, and it is smaller than the thickness of polyethylene tie layer and MLLDPE layer. The leakage id the 1L bag is test and results are shown in Table 4. There has no leakage in the 1L bag. There has corrosion spot on the bag.

| Days | Thickness (mm) | Relative value for reduce(%) |
|------|----------------|------------------------------|
| 0    | 0.1565         | 0                            |
| 30   | 0.1508         | 3.6                          |
| 60   | 0.1496         | 4.4                          |
| 90   | 0.1485         | 5.1                          |
| 750  | 0.1340         | 14.4                         |
3.3. Mechanical property of the complex film

1-liter bag is made of the new complex film. Emition with additive is filled in the bag. The bag with emition with additive for astronaut has been stored for 750 days. The sample of the bag with water is shown in Figure 2. Mechanical properties of the complex film are shown in Table 5. The stretching intensity at length direction decreases by 3.4% when the 1-liter complex film bag with emition with additive was stored for 750 days. The stretching strain at length direction increases by 8.3% for 750 days. The stretching intensity at landscape orientation decreases by 13.2%, while the stretching strain at landscape orientation doesn’t change for 750 days. Longitudinal right angle tear strength fluctuates with 5% during the 750 days. Right angle tear strength decreases with 8% after 750 days, and stretching intensity of heat-seal reduced by 11.4% after 750 days.

| Days | Leakage (Pa•m³/s) |
|------|-------------------|
| 0    | 2.3×10⁻⁶         |
| 30   | 1.8×10⁻⁶         |
| 60   | 2.5×10⁻⁶         |
| 90   | 2.7×10⁻⁶         |
| 750  | 2.1×10⁻⁶         |

3.4. Leakage of 1L bag

Figure 2. 1-liter complex film bag with emition with additive.

Figure 3. Stretching intensity curve.

Figure 4. Stretching strain curve.
The stretching intensity curve for the test is shown in Figure 3. The stretching strain curve for the test is shown in Figure 4. It can be seen that the maximum change is stretching intensity at landscape orientation during 750 days. All test parameters meet the demand of design condition.

Table 5. Test parameters of the complex film.

| No. | Test parameters                                      | Condition for test | Test result (days) |
|-----|------------------------------------------------------|--------------------|--------------------|
|     |                                                     |                    | 0 | 30 | 60 | 90 | 750 |
| 1   | Stretching intensity at length direction (MPa)       | Test speed 100 mm/min | 3.6×10^2 | 3.7×10^2 | 3.8×10^2 | 4.0×10^2 | 3.9×10^2 |
| 2   | Stretching strain at length direction (%)           | Distance 25 mm     | 36.4 | 36.0 | 34.7 | 35.3 | 31.6 |
| 3   | Stretching intensity at landscape orientation (MPa) | Test speed 100 mm/min | 3.9×10^2 | 3.8×10^2 | 3.8×10^2 | 3.8×10^2 | 3.9×10^2 |
| 4   | Stretching strain at landscape orientation (%)     |                    | 3.9×10^2 | 3.8×10^2 | 3.8×10^2 | 3.8×10^2 | 3.9×10^2 |
| 5   | Longitudinal right angle tear strength (kN/m)       | Test speed 200 mm/min | 131 | 113 | 123 | 121 | 128 |
| 6   | Right angle tear strength (kN/m)                    |                    | 124 | 111 | 118 | 124 | 114 |
| 7   | Stretching intensity of heat-seal (N/min)           | Test speed 300 mm/min | 59.6 | 59.0 | 50.7 | 57.4 | 53.1 |

4. Conclusions

The compatibility experiment and mechanical properties experiment showed that the nine layer film has good compatibility with emiction with additive in space station. The complex film has great chemical corrosion-resistance property. The height of nine layers film decreases by 5% after 90 days and it decreases by 13.6% after 750 days. The corrosion on the film just reaches the second layer which is polyethylene tie layer. Stretching intensity and stretching strain decrease only by 7% during the storage process, while the elongation at break has no change basically. The mechanical property of the complex film also meets the requirements for storing emiction with additive after 750 days. The nine layers film material can be used to store emiction with additive for more than 2 years. It offers a new method for the design and application of liquid container in China space station.

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