Stress Corrosion Cracking Behavior of LD10 Aluminum Alloy in UDMH and N₂O₄ propellant

Youhong Zhang*, Xinlong Chang and Wanlei Liu
Xi’an Research Institute of Hi-tech, Xi’an, China

*Corresponding author e-mail: zyhnpu@163.com

Abstract. The LD10 aluminum alloy double cantilever beam specimens were corroded under the conditions of Unsymmetric Uimethyl Hydrazine (UDMH), Dinitrogen Tetroxide (N₂O₄), and 3.5% NaCl environment. The crack propagation behavior of the aluminum alloy in different corrosion environment was analyzed. The stress corrosion cracking behavior of aluminum alloy in N₂O₄ is relatively slight and there are not evident stress corrosion phenomenons founded in UDMH.

1. Introduction
The UDMH and N₂O₄ are the two popular kinds of liquid propellant and used in the field of carrier rocket, torpedo, attitude control equipment, orbit control and so all [1]. Due to the corrosive, inflammable, explosive and high toxicity character of UDMH and N₂O₄, the service and storage environment is very critical [2]. Liquid propulsion system components must be capable of satisfactory operation after years of exposure to highly reactive propellants while retaining the propellant without leakage under severe ambient conditions of stress loading [3-4]. When the liquid propellant tankage made in LD10 aluminum alloy are used for storing UDMH and N₂O₄, it shall endure the stress which caused by the gas in the tankage and missile gravity[5]. It is necessary to study the SCC character of the aluminum alloy served in liquid propellant environment, there have been a mount of research work on the stress corrosion cracking behavior on kinds of high strength aluminum alloy [6], however, because of the hypertoxic character of UDMH and N₂O₄, the SCC experiment is very dangerous. So, there are still no SCC experiment reports in UDMH and N₂O₄ environment, and there are only limited documents about of the material corrosion study in liquid propellant environment.

2. Experimental work
The material used in this investigation is LD10 high strength aluminum alloy supplied in the form rolled plate (19mm thickness value). The alclad was machined out from the aluminum alloy plate firstly, and the double cantilever beam (DCB) specimens were made and the initial crack was made used the wire discharge machining [7].

The SCC experiment procedure is as follows: firstly, the three components (including 3 specimens) of was loaded to anticipated values of stress intensity factor. The stress intensity factor values of three components are briefly 80, 60 and 40 Kg/mm1/2. Secondly, the loaded DCB specimens were put into three solutions which were 3.5% NaCl, N₂O₄ and UDMH. The SCC experiment was carried out in closed container, the notch face of the specimen is up, and the corrosion liquid level is higher than the pre-machined fatigue crack and lower than the loading bolt. The specimen was taken out from the closed container every 15 days and the values of crack length were read from the optical microscope. At last, the experiment was terminated until the situation of no crack propagation was observed, then,
after the experiment, the specimen was taken out and the final crack length was recorded and calculated out the values of the initial stress intensity factor.

3. Results and discussion
After the SCC experiment, the specimens were taken out and draw to fracture failure and the fracture morphology was observed using SEM (shown in Figure.1).

As can be seen in Figure.1, the fracture morphology of LD10 aluminum alloy reveals different character in different corrosion solution. In 3.5% NaCl solution, the fracture morphology of the specimens presents typical brittleness fracture. Where the corrosion production cover, its configuration shows ramous, and the typical morphology of intergranular stress corrosion cracking, that is river-like flower pattern, was found (Figure.1.a).

In N$_2$O$_4$, the fracture part covered a layer of oxide film, and the fracture character is intervenient of brittle fracture and mechanical fracture. It can be seen partly river-like flower pattern, and also alloy dimple. It suggests that the SCC phenomena happen at local position. In UDMH, there is not corrosion production on fracture morphology, and no evidence of the SCC.
Because of the crack length of the specimen in UDMH solution vary title during the experiment time, only the average crack growth velocity can be measured. Because of no obvious SCC growth character, only the curves of SCC growth speed V to K of the specimens in 3.5% NaCl solution and N₂O₄ are presented in Figure.2.

![Figure 2: V-K curves of aluminum alloy in 3.5% NaCl and N₂O₄](image)

From the Figure.2, it can be seen that the stress corrosion crack growth curve of the specimen in 3.5% NaCl solution reveals obvious platform zone, with the increasing of the stress intensity factor, the crack growth ratio increase firstly, and then remain on a platform level. The platform zone named as the second zone, and the crack growth ratio on the second zone is attended on engineering field.

The stress corrosion crack growth ratio of the specimen in N₂O₄ increases with the largenning of the stress intensity factor, and at last, the crack growth ratio varies gently. The stress corrosion crack growth ratio of the specimens in N₂O₄ is smaller than it in 3.5% NaCl solution. The stress intensity factor corresponding to initial crack growth in N₂O₄ is larger than it in 3.5% NaCl solution. Table.1 lists the critical SCC stress intensity factor and average crack growth ratio of LD10 aluminum alloy in different corrosion solutions.

| Corrosion environment | K_I (Kg/mm1/2) | K_sc (Kg/mm1/2) | da/dt (mm/s) |
|-----------------------|----------------|-----------------|--------------|
| 3.5% NaCl             | 80.71          | 55.93           | 1.43×10⁻⁶    |
|                       | 65.16          | 56.37           | 5.81×10⁻⁷    |
|                       | 42.33          | 41.20           | 2.43×10⁻⁷    |
| N₂O₄                  | 81.13          | 73.03           | 4.43×10⁻⁷    |
|                       | 63.06          | 62.32           | 4.80×10⁻⁸    |
|                       | 41.94          | 41.81           | 1.20×10⁻⁸    |
| UDMH                  | 80.35          | 80.23           | 5.10×10⁻⁹    |
|                       | 63.45          | 63.43           | 1.00×10⁻⁹    |
|                       | 61.19          | 61.17           | 1.00×10⁻⁹    |

4. Conclusion
The LD10 aluminum alloy DCB specimens were corroded under the conditions of three different corrosion environments. The surface corrosion damage degree in different environments is different, and the corrosion sensitivity of the specimen in 3.5% NaCl solution is the most serious. The second is in N₂O₄, and there is not obvious change on the specimen in UDMH. The stress corrosion cracking behavior of aluminum alloy in 3.5% NaCl is very acute, and it is relatively slightly in N₂O₄ and it...
reveals no evident stress corrosion phenomenon in UDMH. All these work is helpful to the serving safety evaluating of liquid propellant tankage made in LD10 aluminum alloy.

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