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To cite this article: Yuanzheng Huang *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **452** 022119

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Study on Plugging of UDMH Storage Tank Leakage by Epoxy Adhesive

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Abstract. In this paper, the thermal stability of epoxy adhesive castings and their compatibility with UDMH were studied. The influence of UDMH on tensile shear strength was investigated, and the simulated leakage plugging of UDMH tank was carried out. The results show that the thermal decomposition temperature of epoxy adhesive is 200 °C, which meets the requirement of heat resistance for leakage plugging. Epoxy resin castings have good compatibility with UDMH. The mass change rate of epoxy resin castings is less than 7% after soaking at room temperature for 15 days, and the surface of the specimens is smooth and free of cracks after immersion. The tensile shear strength of UDMH wetting on bonded metal surface increases a little. With the aid of clamping fixture, the simulated plugging of weld seam and sand whole defects of UDMH tank can be realized effectively.

1. Introduction

Unsymmetrical dimethyl hydrazine (UDMH), which is flammable, explosive, highly toxic and corrosive, is usually stored in large quantities as liquid propellant. Material defects, corrosion and accidental impact of UDMH tank materials are the main reasons causing leakage. The leakage point should be plugged as soon as possible to avoid or reduce the further damage. Epoxy adhesive plugging material has the characteristics of flexibility, rapidity, firmness, reliability, which is favored in the leakage plugging treatment of UDMH.

The plugging materials should have good compatibility with leakage medium. In this paper, the corrosion resistance of epoxy adhesive was researched by the mass change rate of cured epoxy adhesive before and after soaking in UDMH, and the compatibility of epoxy adhesive and UDMH was studied. The main reasons for the leakage of UDMH tank are the corrosion and defects of welding seam at the junction of tank barrel and head, the perforation caused by corrosion or impact of tank, and the sand holes left in the casting process of tank body, which are the main reasons for the leakage of UDMH tank. The model of UDMH tank with weld defect and keyhole defect was used to simulate plugging.

2. Experiments and methods

2.1. Experimental raw materials and instruments

UDMH, analytical pure, University of Rocket Army Engineering; UDMH tank model (304 stainless steel), epoxy resin adhesive, self-made; stainless steel clamps, silicone gaskets, commercially available;



Electronic universal testing machine, Sans CMT 7204, range 0-20KN; Scanning electron microscope, Vega II XMU; TG-DSC Analyzer SDT-Q600.

2.2. Detection and characterization

TG analysis: After curing for 7 days, epoxy resin casting was analyzed by thermogravimetry. The temperature rising range was 25-700°C in N₂ atmosphere, and the heating rate was 20°C/min.

Corrosion resistance of epoxy adhesive to UDMH: Referring to the alkali resistance test of epoxy resin cast in GBT2567-2008, the epoxy resin was cast into 80 × 15 × 4 mm strip and curing at room temperature. The splines were immersed in UDMH at room temperature (20-30°C). After a period of soaking, the residual liquid on the surface was absorbed dry by filter paper. The Mass change rate $\Delta\omega_t$ was calculated, and the change of surface morphology of the splines was recorded. The formula for calculating $\Delta\omega_t$ is shown as the formula. In the formula, m_1 is the mass of the splines after soaking for a period of time and m_2 is the initial mass of the splines.

$$\Delta\omega_t\% = \frac{m_1 - m_0}{m_0} \times 100\% \quad (1)$$

SEM analysis: The surface of the sample was sprayed with gold and analyzed by scanning electron microscope.

Tensile shear strength measurement: According to GBT7124-2008, the tensile strength of the adhesive was measured using a single lap of 45[#] carbon steel.

3. Results and analysis

3.1. Results and analysis of soaking of castings

Figure 1 shows the mass change rate of epoxy adhesive castings soaked in UDMH for 15 days. It shows that $\Delta\omega_t$ increases with increasing soaking time, $\Delta\omega_t$ increases obviously in the early stage of epoxy resin immersion (1-9 days), $\Delta\omega_t$ tends to saturate in the later stage of immersion, $\Delta\omega_t$ is less than 7% in 15 days. The increase of $\Delta\omega_t$ may be due to the presence of a large number of polar groups such as amino group, ether bond, hydroxyl group and amide group in the cured epoxy adhesive, while UDMH itself contains primary amine and tertiary amine with strong polarity. The intermolecular interaction force can be formed with the polar groups in the casting body, besides, the network crosslinking density is not very high after the long chains curing agent is solidified, and the UDMH can enter into the network structure and form physical adsorption on the surface of the casting body. This kind of swelling is not enough to destroy the bulk structure of the casting. The adsorption amount reaches saturation after a certain period of time, and $\Delta\omega_t$ tends to be stable.

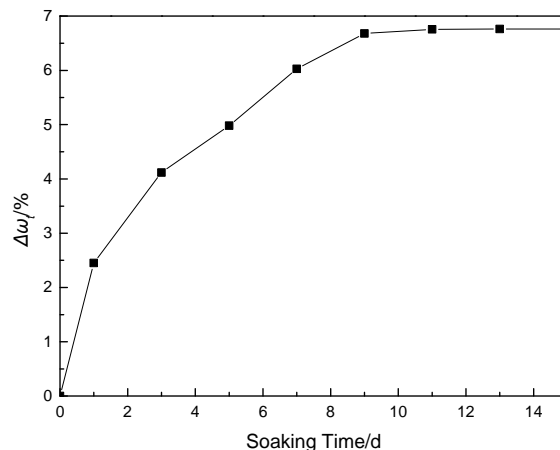


Figure 1. Quality change rate of epoxy cast during 15 days soaking

Figure 2 and Figure 3 are the surface morphology and SEM images of the samples before and after 15 days immersion in epoxy castings, respectively.

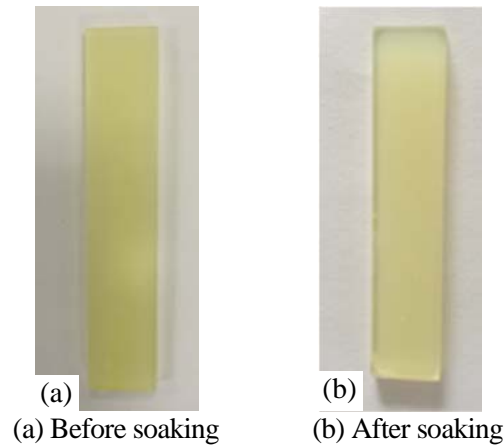


Figure 2. Morphology before and after immersion

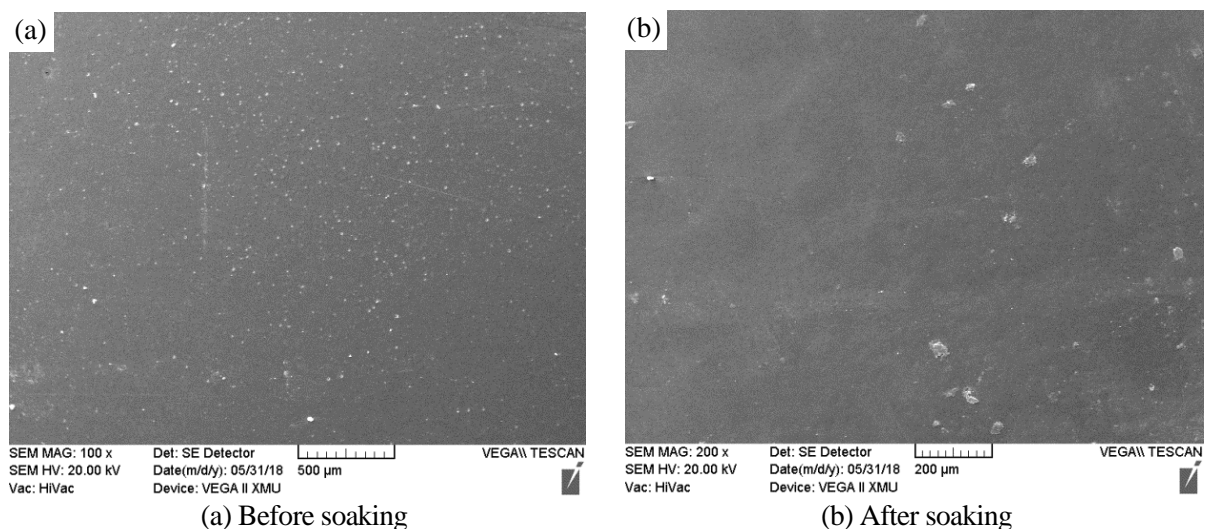


Figure 3. SEM before and after immersion

It can be seen from Figure 2 that the surface of the macrostructure of the sample block is smooth after 15 days of soaking, and no crack occurs. It is shown in the SEM image before and after soaking that the stress cracking caused by the swelling effect does not appear in the microstructure of the cast body after soaking, which indicates that the UDMH adsorbed inside the cast body is not enough to destroy its own three-dimensional network structure. Therefore, the epoxy resin has a good resistance to UDMH corrosion resistance.

3.2. Epoxy adhesive TG analysis

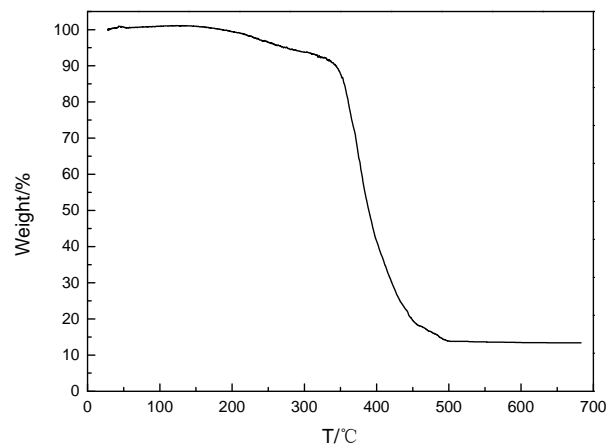


Figure 4. TG diagram of casting body

Figure 4 is the thermogravimetric analysis diagram of epoxy adhesive. It can be seen from the diagram that the mass of the casting has not changed basically before 200 °C, and the thermal decomposition of the casting begins after 200 °C. The weight loss of the casting body is 10% and the temperature is 342 °C. When the weight loss is 50% at 380 °C and 500 °C, the final weight loss rate is 86.16%, and the thermal decomposition of the cast is complete and the mass does not change. The storage temperature of UDMH is usually 15-35 °C, so the thermal stability of the material can meet the environmental temperature requirements for UDMH tank leakage plugging.

3.3. Simulated plugging results and analysis

Figure 5 and Figure 6 show the effect of simulated weld and sand whole plugging. It can be seen from the figure that the cured adhesive re-forms a dense sealing layer at the leaking part. The plugging adhesive solidifies within 30 min, and the high shearing shear the strength (14.77 MPa) determines the seal layer formed to have a strong reinforcing effect.



Figure 5. Weld simulation plugging diagram

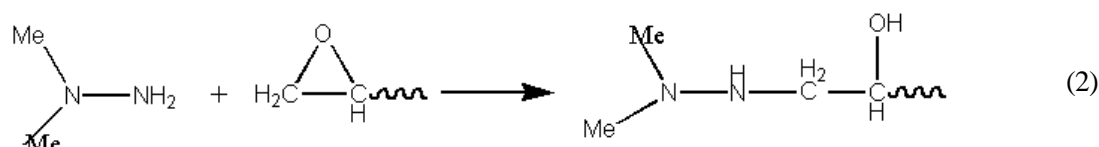


Figure 6. Sand whole simulation plugging diagram

Figure 5 and Figure6 show the effect of simulated weld and sand whole plugging. It can be seen from the figure that the cured adhesive re-forms a dense sealing layer at the leaking part. The plugging

adhesive solidifies within 30 min, and the high shearing shear the strength (14.77 MPa) determines the seal layer formed to have a strong reinforcing effect.

The tensile shear strength of the sheared metal sheet after surface infiltration of dimethyl hydrazine is 15.03 MPa, which is slightly higher than the tensile strength of the sample which is not infiltrated by dimethyl hydrazine. This may be due to the presence of small molecules on the surface. UDMH can react with epoxy adhesive to cause higher crosslinking density after curing of epoxy resin. The reaction equation is as shown in the following formula.



4. Conclusion

After curing, the epoxy adhesive has good compatibility with UDMH. The mass change rate of the cast body after immersion for 15 days at room temperature is less than 7%, and there is no stress cracking. The uncured epoxy adhesive reacts with UDMH to form a high crosslink density, which improves bond strength. The epoxy adhesive has good heat resistance and the thermal decomposition temperature is more than 200 °C, which meets the needs of use.

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