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Design and performance study on adaptive sealing of a dry cabin for maintenance of submarine pipeline

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S1 Uniaxial test

To determine the parameters in the Mooney-Rivlin hyperelastic model, uniaxial tests on silica gel samples were carried out. As shown in Fig. S1a, tensile tests were carried out on silica gel samples by using an electronic universal testing machine (5000N, 10^{-5}N, Zwick/Roell 5.0TN, Germany). The drawing rate is 10mm/min. As shown in Fig. S1b, the sample was processed into dumbbell type according to the standard (GB/T528-2009; IS037:2005). As shown in Fig. S1c, compression tests were carried out on silica gel samples by using an electronic universal testing machine (2500N, 10^{-5}N, Zwick/Roell Z020, Germany). The compression rate is 1mm/min. As shown in Fig. S1d, the sample was made into a cylinder according to the standard (GB/T 7759.1-2015; ASTM D395). The sample diameter is 13mm and the height is 6.3mm.

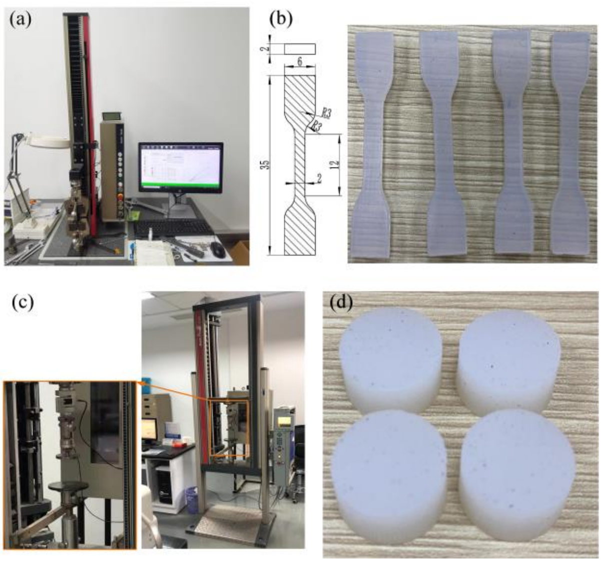

Fig. S1 (a) Electronic universal testing machine in the tensile test, (b) silica gel dumbbell sample, (c) electronic universal testing machine in the compression test, (d) silica gel cylindrical sample

S2 Airbag test study

S2.1 Airbag expansion test

To test the expansion of the customized airbag under different air pressures, the test system shown in Fig. S2 was built. The test data is compared with the simulation data to verify the accuracy of the constitutive model describing elastic deformation of the airbag, and the accuracy of ABAQUS to simulate the inflating deformation of the airbag. As shown in Fig. S2, an air compressor was used to inflate the airbag in the test, and the air pressure during the inflation process was measured by the pressure sensor. To continuously and accurately measure the height of the airbag expansion, a laser rangefinder (RXJ-100, measuring range 100m, accuracy 1mm) was used to measure the displacement at the highest position of the airbag. The pressure and expansion height during the test were stored in the computer by the acquisition circuit board. The air compressor used in the test is an oil-free quiet high-pressure small industrial air compressor (Outstanding, 0.7MPa, 100L/min). The pressure sensor is a diffused silicon piezoresistive hydraulic sensor (Hangjia Technology, measuring range 4MPa, accuracy 0.001MPa).

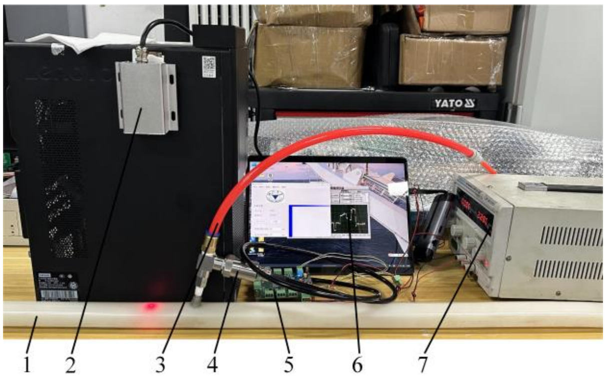

Fig. S2 Airbag expansion test system. 1-airbag, 2-laser rangefinder, 3-air compressor gas pipe, 4-pressure sensor, 5-acquisition circuit board, 6-computer, 7-DC power

S2.2 Airbag seal pressure test

To verify the accuracy of airbag sealing simulation results, a sealing test device as shown in Fig. S3a was built, and the corresponding real object is shown in Fig. S3b. Due to the large size of the dry cabin, the sealing test using the dry cabin will take a lot of time to replace the airbags and pressurize the cabin with water. Therefore, we designed a small cabin to test the sealing performance, and the dimensions of the airbag remain the actual size used. Therefore, the built sealing test device does not belong to the scale ratio test, and there is no need to study the similarity theory.

In the test, the air compressor was used to provide the air source for the booster pump, and the booster pump provide the high-pressure liquid for the sealing test cabin. The booster pump is the gas-liquid booster pump (USUN-AH02, 45MPa, 56.55L/min). The other outlet of the air compressor is used to inflate the airbag, and a pressure sensor is connected at the interface to measure the air pressure inside the airbag. The sealing performance can be reflected by the pressure drop of the test cabin, the pressure during the test is measured by the pressure sensor and stored in the computer.

Fig. S3c-5e shows the sealing test flow. First, the sealing test device was set up according to Fig. S3a and Fig. S3b. As shown in Fig. S3c, the airbag was installed on the inner surface of the outer cylinder and fixed with glue. After the glue has cured, the outer cylinder was filled with water. As shown in Fig. S3d, then, the needle valve at the top of the inner cylinder was opened and the inner cylinder was slowly inserted into the outer cylinder. The air compressor was turned on to inflate the airbag to the required pressure. As shown in Fig. S3e, the booster pump was opened to pump water into the test cabin. When liquid leaks from the needle valve, it means that the cabin has been filled with water. At this point, the needle valve was closed. The increase in cabin pressure can be achieved by continuing to increase the pressure with the booster pump.

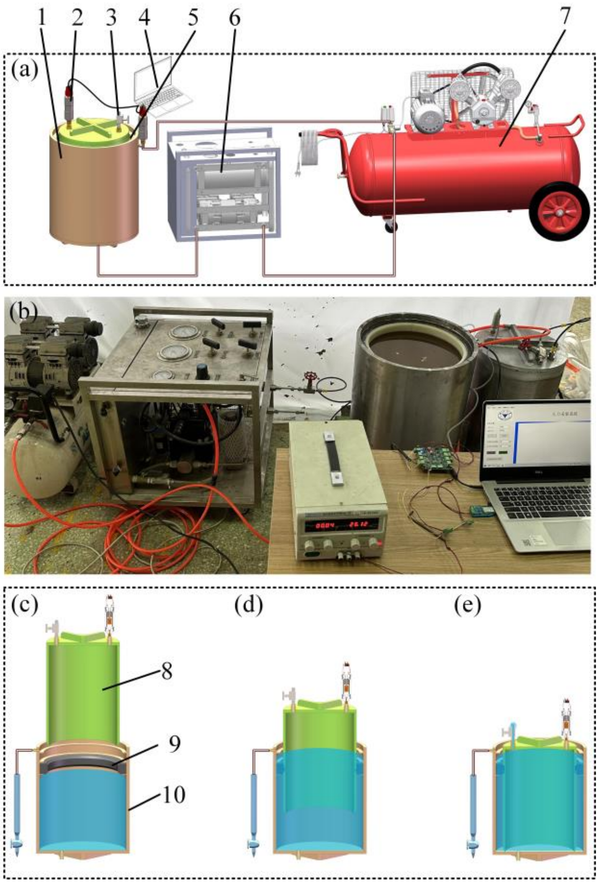

Fig. S3 (a) Schematic diagram of the sealing test device, (b) physical diagram of the sealing test device, (c) test step 1, (d) test step 2, (e) test step 3.

1-test cabin, 2-pressure sensor, 3-needle valve, 4-computer, 5- water channel, 6-gas-liquid booster pump, 7-air compressor, 8-inner cylinder, 9-air bag, 10-outer cylinder.

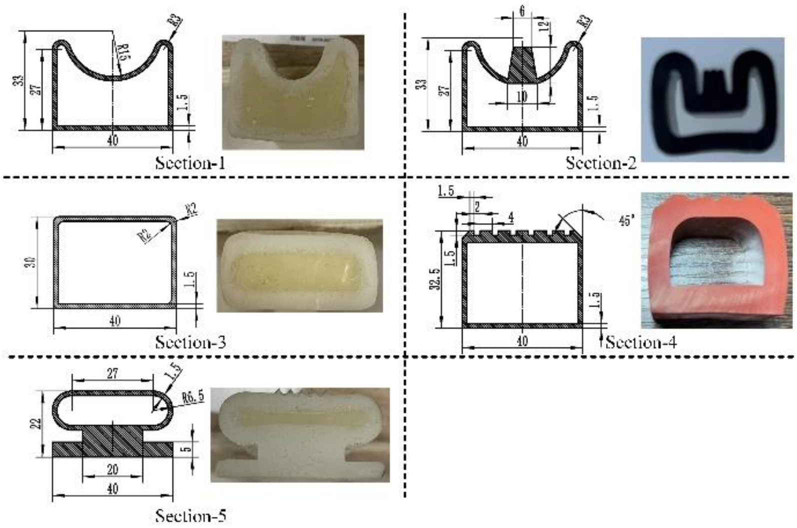

Fig. S4 Dimensions and physical drawings of airbags with different cross-section shapes