Inter J Nav Archit Oc Engng (2012) 4:302~312
http://dx.doi.org/10.2478/IJNAOE-2013-0098

Study on the pressure self-adaptive water-tight junction box in underwater vehicle

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ABSTRACT: *Underwater vehicles play a very important role in underwater engineering. Water-tight junction box (WJB) is one of the key components in underwater vehicle. This paper puts forward a pressure self-adaptive water-tight junction box (PSAWJB) which improves the reliability of the WJB significantly by solving the sealing and pressure problems in conventional WJB design. By redundancy design method, the pressure self-adaptive equalizer (PSAE) is designed in such a way that it consists of a piston pressure-adaptive compensator (PPAC) and a titanium film pressure-adaptive compensator (TFPAC). According to hydro-mechanical simulations, the operating volume of the PSAE is more than or equal to 11.6 % of the volume of WJB liquid system. Furthermore, the required operating volume of the PSAE also increases as the gas content of oil, hydrostatic pressure or temperature difference increases. The reliability of the PSAWJB is proved by hyperbaric chamber tests.*

KEY WORDS: Underwater vehicle; Pressure self-adaptive equalizer; Water-tight junction box; Redundancy design.

INTRODUCTION

Ocean covers about 71 percent of the earth's surface and contains abundant resources. The development of ocean resources can be the final solution to some global science and engineering issues such as the study of origin of life, development of new resources, the improvement of human living condition, social sustainable development and so on (Jiang, 2000; Chen, Yang, Gu and Ye, 2003; Wang, Yuan, Li and Jiao, 2011; Nihous, 2007; Izadparast and Niedzwecki, 2011). However, the underwater environment (e.g., high pressure) makes underwater resource exploration quite challenging, especially in deep sea. Nowadays, with the development of marine technology, a variety of underwater vehicles have been developed and are playing an important role in underwater resource exploration, inspection and operation (Li, et al., 2009; Bessa, Dutra and kreuzer, 2010; Fang, Hou and Luo, 2007).

Underwater vehicles use multiple sensors, working components and control systems to achieve precise movement and accomplish certain tasks. Water-tight junction boxes (WJB) are used to protect the connections between sensors and working components from water and ensure the reliability of underwater vehicles (Chyba, Haberkorn, Smith and Choi, 2008; Bagheri, Karimi and Amanifard, 2010). As the water depth increases, WJBs suffer from increasing external water pressure. If the WJB uses pressure hull design, the structure of the WJB will be simple but the size and weight of the WJB will be increased significantly. The cumbersome WJB will occupy a large space, thus increasing the weight of the underwater vehicle and degrading the power efficiency, maintainability and reliability of the underwater vehicle (Zhang, Luo, Wang and Gu, 2007). From the other hand, if the WJB is connected with an external pressure compensator, then the internal and external pressure can be

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balanced; however, some hidden dangers occur, e.g., pipe blockage, leakage, corrosion and damage of external compensator.

This paper puts forward a pressure self-adaptive water-tight junction box (PSAWJB) using a piston pressure-adaptive compensator (PPAC) and a titanium film pressure-adaptive compensator (TFPAC), which makes the pressure shell more light-weight. The pressure self-adaptive equalizer (PSAE) doesn't need any external compensator or oil line. Therefore the complexity of the structure is reduced and some hidden dangers (e.g., pipe blockage, leakage, etc.) are avoided. The PPAC makes the internal pressure always a bit higher than the external water pressure such that external water is prevented from leaking into the oil chamber. Titanium has large deformation range and excellent aging resistance, therefore selected for the film of the pressure-adaptive compensator. By this two-compensator design, the reliability of the WJB is improved significantly.

DESIGN OF PSAWJB

"Pressure self-adaptive" means that it can automatically change its pressure according to the external pressure. There are many types of pressure self-adaptive compensators, such as metal film type, bag type, corrugated pipe type and piston type of pressure compensator (Cao, et al., 2011; Meng, Wang, Wei and Zhang, 2000). The working principles of the metal film type, bag type and corrugated pipe type of pressure compensators are similar, which are commonly featured as a thin-wall vessel that allows a certain degree of elastic deformation (Meng, Wang, Wei and Zhang, 2000). The PPAC is designed using non-elastic shell. Pressure compensation is achieved by volume change in the piston chamber (Zhang, Luo, Wang and Gu, 2007). Consider the limited space in medium sized work-class underwater vehicles in deep-sea high pressure environment, these pressure compensators have certain disadvantage. Metal film, bag and corrugated pipe types are pressed by seawater to cause elastic deformation. The pressure of the external water is always higher than the internal oil during deformation, such that, external water might leak into the oil chamber and lead to short-circuit in electronic devices. Materiel of most bag and corrugated pipe are rubber which ages easily in seawater. Although corrugated pipe type can be made of Titanium, it is difficult in processing. Deep-sea environment need large volume of compensation which lead to a large and heavy piston. Pressure compensators' characteristics are summarized in Table 1.

Table 1 Characteristics of several types of pressure compensators.

Compensators / Characteristics	Metal film	Bag	Corrugated pipe (rubber)	Corrugated pipe (Titanium)	Piston	PSAWJB
Non-leakage	×	×	×	×	√	√
Anti-aging	√	×	×	√	√	√
Compact structure	√	√	√	√	×	√
Light Weight	√	√	√	√	×	√
Easy process ability	√	√	√	×	√	√

Considering the characteristics of several types of pressure compensators in Table 1, PSAWJB is put forward in this paper. The PSAWJB has the following merits: a PPAC is used for pressure compensation which makes the internal pressure always a bit higher than the external pressure, thus preventing external water from infiltrating the oil chamber. Using the redundancy design method, a TFPAC is used as volume compensation, making the PPAC design more compact and more reliable. Titanium of the TFPAC is resistant to seawater corrosion and aging, thus improving the lifetime of the structure. By this design, the PASWJB can be an appropriate pressure self-adaptive system in deep-sea environment.

The overall design

Schematic of the PSAWJB in underwater vehicle presented in this paper is shown in Fig. 1. Fig. 1(a) is the explosion view, showing the structure of the PSAWJB and its main components. Fig. 1(b) is the wire frame showing the dimensions of the PSAWJB (400 *mm* in length, 230 *mm* in width and 278 *mm* in height). The PSAWJB in this paper is fitted with medium sized work-class underwater vehicles.