A study of transducers with different monitoring surfaces for assessing the condition of cavitation activity

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Abstract. Cavitation has received increasing attention worldwide due to its wide application in both medical and industry fields. The condition of cavitation activities takes a key role in its practical application, and it is passive cavitation detector (PCD) that is always used to detect real-time cavitation conditions. This paper reports the performance of a novel curved PCD that improved based on traditional PCD with a plane surface. It was found that the curved PCD had better sensitivity than the plane one and its optical operating area as well as critical performance points were also given. Based on this study, monitoring the performance of PCD can be improved for cavitation detection, especially in industrial fields that use stable cavitation technology.

1. Introduction

There is considerable interest in cavitation technology for its wide use in both industrial and medical fields, such as ultrasonic cleaning [1] and blood-brain-barrier opening [2], which offers significant economic benefits. Acoustic cavitation is the formation and subsequent collapse of micro-bubbles under ultrasound waves in liquid like water [3]. Generally, there are two basic kinds of cavitation activities: stable and inertial activities. This classification approach is based on the lifetime of microbubbles generated during the cavitation period. Different applications can be made on account of the characteristics and subsequent phenomena like light emission and chemical reaction of certain cavitation conditions [4]. However, the identification of different cavitation conditions is still challenging due to the relatively low sensitivity of the cavitation sensor [5].

Nowadays PCD has become a common tool for receive acoustic information and transform them into electric signals, having superiority in non-contact detection, is widely used in the monitoring of cavitation activities [6]. PCD can distinguish different cavitation activities according to their frequencies. Nevertheless, the current monitoring precision of PCD cannot satisfy the growing requirement of high-accuracy detection [5]. To solve this problem, various improvements of PCD have been proposed, changing the material and shape of PCD in particular, which hence the detecting accuracy to a certain degree. Although the effect of the improvement of cavitation detectors over decades, little attention has been paid to the comparison between PCD with different monitoring surfaces.

The present paper describes a series of objective comparisons between novel curved PCD and traditional plane PCD via the finite element method (FEM). Through analyzing the acoustic information received by PCD, the performances of these two PCDs were compared and their optimum operating areas were given, which is hoped to guide further related study.
2. Methods
A series of FEM models of both plane and chosen curving PCDs were established in a commercially available FEM software, Onscale. The applied materials of basic components of PCDs are shown in Fig. 1. Meanwhile, to ensure the detecting areas are the same, different radii of PCD surfaces were chosen, considering the concave area is a bit larger than the plane area. Thus, the radius of the plane and curving PCDs were 10mm and 9.68mm respectively.

![FEM schemes of the plane and curving PCDs.](image)

Figure 1: FEM schemes of the plane and curving PCDs.

The driving source of simulations was 500kHz sine waves, and the maximum acoustic pressures were given in Fig. 2. The result shows that the optimal working area of the plane and curving PCDs are different, and the monitoring accuracy of curving PCD is almost 1.6 times of plane one. Based on this information, it can be indicated that there could be critical points of the monitoring performance between these two PCDs. To compare their detecting accuracy in more detail, the acoustic pressures within the working range were given and discussed in the following.

![the max acoustic pressure of the plane and curving PCDs.](image)

Figure 2: the max acoustic pressure of the plane and curving PCDs.

3. Results and Discussion
Based on the maximum pressure figure, the curving PCD has a good monitoring performance in its focusing area, while once beyond this range, its detecting accuracy could be descending fast. In combination with the pressure field of plane PCD, its monitoring ability in the far area remains in a relatively good range. Thus, we measured the detected acoustic pressure near the focusing field (about 40mm away from the surfaces of two PCDs) and the results are illustrated in Fig. 3 and Table 1.
Figure 3: Normalized acoustic pressure of the plane and curving PCDs. (a) detected at 40mm. (b) detected at 41mm.

Table 1: Rise time (RT) and full-width-half-maximum (FWHM) of the plane and curving PCDs.

| PCD    | RT [ns] Curved/Plane | FWHM [ns] Curved/Plane |
|--------|----------------------|------------------------|
| At 30mm| 778.09/775.87        | 777.10/768.76          |
| At 40mm| 809.17/807.15        | 804.99/780.78          |
| At 41mm| 804.02/805.97        | 757.71/777.09          |

The monitoring performance of both two simulated PCDs can be seen directly from Fig.3, the detecting ability of the curving PCD is significantly higher than plane one due to its focusing effect when the detecting point was located at 40mm away from the detecting surface, while the plane PCD had better monitoring precision at 41mm location. This is because the focusing effect drops remarkably once beyond the focusing area. Therefore, 40mm is one of the critical points of the detecting performance between the plane and curving PCDs. To determine whether there is another critical point, we also compared the measuring performance of the two PCDs in the near area. Table 2 shows the related acoustic information for each detected PCDs. At the center of detecting surface and 1mm location, both RT and FWHM of plane PCD are slightly higher than the curving one. But when the point was set at the 2mm location, the monitoring ability of curving PCD is notably higher than the plane PCD. Altogether, the plane and curving PCD have their optimal working range, and their critical points are 1mm and 40mm respectively.

Table 2: RT and FWHM of the plane and curving PCDs at the near field.

| PCD    | RT [ns] Curved/Plane | FWHM [ns] Curved/Plane |
|--------|----------------------|------------------------|
| At 0   | 304.98/316.54        | 716.44/728.60          |
| At 1mm | 307.26/347.42        | 712.79/728.94          |
| At 2mm | 446.84/383.51        | 614.62/589.34          |

4. Conclusions

In this article, the detecting performance of plane and curving PCDs were compared via FEM simulations. The curving PCD has better monitoring ability in its focusing areas, but this ability also declines quickly beyond the focusing range. By contrast, the plane PCD possesses a higher RT and full-width-half-maximum value in both near and far area. Based on this finding, the critical points of measuring the performance of these two PCDs were discovered, which were 1mm and 40mm, and can therefore satisfy the previous assumptions.
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