Conclusions

The overall conclusions drawn from the various studies on the annular ring and annular cylindrical arrays are presented in this chapter. The various results obtained are highlighted. This chapter concludes with a brief note on the scope for further work in this field.

Generally single probe techniques are used for underwater pipeline inspection. In this case the probe has to be rotated around the pipeline as well as moved along its length. This is a tedious and time consuming process. So there is a requirement to develop sensors which are much more efficient. The main objective of carrying out
this investigation is to develop suitable transducer array systems so that underwater pipeline inspection could be carried out in a much better way, a focused beam and electronic steering can reduce inspection time as well. Annular ring and annular cylindrical array models have been developed to be used effectively for pipeline inspection. Better results are obtained by optimising the array parameters. Selectively energised sections of the annular ring and annular cylindrical arrays placed concentric over the pipeline are studied. The beam characteristics and effective acoustic pressures of these arrays are studied for different array parameters. A theoretical model has been developed assuming point source of elements and therefore the effects due to the finite size of the elements are to be taken into account when the realisation of the array is effected. The spacing between the elements is assumed to be half the wavelength so that the interelement interaction is minimum. For NDT applications these arrays are operated at MHz range. The wavelengths become very small in these frequency ranges. Then the size of the array elements becomes very small, requiring hybrid construction techniques for their fabrication. Though single transducer elements operating in 1-10MHz range have been fabricated using PVDF as the active material, the array could not be constructed due to technical limitations. The design aspects and calibration of these transducer elements are described in the appendix.

6.1 HIGHLIGHTS

A theoretical model of a point source annular ring array and an annular cylindrical array have been developed in the course of this research work for inspection of underwater pipelines. An annular ring or annular cylindrical array with optimised array geometry and configuration can be effectively used for pipeline inspection with
a good focusing effect and reduced inspection time. The different parameters that are varied and optimised in the computations are the number of elements in the section, radius of array, radius of pipeline and axial distance between the array and pipeline. With electronic switching the ultrasound beam can be shifted over the complete contour of the pipeline. A good focusing effect of the annular ring and annular cylindrical arrays makes them much more efficient for flaw detection applications.

For an annular ring array of radius 6cm with element spacing \( \lambda/2 \), operating at 1MHz, the number of elements selectively energised in the section of the array is varied. The beam patterns for the different configurations are shown in Figures 4.4 and 4.5. The sidelobe levels and 3dB beamwidths for different configurations of an annular ring array are shown in Table 4.2. From these results the number of elements are optimised depending on the sidelobe level and 3dB beamwidth acceptable for a particular application.

The beam pattern of a 5 element section of an annular ring array operating at 5MHz is shown in Figure 4.6 for different array radius. The sidelobe levels and 3dB beamwidths corresponding to these variations are tabulated in Table 4.1. It is seen that the 3dB beamwidths and sidelobe levels remain constant when the array radius is \( >40\lambda \).

The beam pattern of a 6x10 element annular cylindrical array compared with that of a 6 element annular ring array is shown in Figure 4.7. The parameters of the annular cylindrical array are varied similar to that of the annular ring array. The results from these computations are tabulated in Tables 4.3 and 4.4. The beam
characteristics are found to remain constant as in the annular ring array when the array radius is $\geq 40\lambda$.

The variation of effective acoustic pressure for different configurations of an annular ring array operating at 5MHz and array radius 3cm is shown in Figure 5.3. The effective acoustic pressure for different configurations of an annular cylindrical array are shown in figure 5.7. The number of elements can be optimised from these results.

A comparison of the effective acoustic pressure of a 21 element linear array and a 21 element annular ring array is shown in figure 5.4. It is seen that the annular ring array has a good focusing effect compared to the linear array.

The axial pressure distribution for different configurations of the annular ring array keeping the array radius fixed at 10cm is shown in Figure 5.5 and Figure 5.6 shows the axial pressure distribution for a 5 element annular ring array. The axial pressure distribution for different configurations of an annular cylindrical array are shown in figure 5.8. The array parameters and the array radius suitable for a particular dimension of the pipeline can be optimised for better performance.

The transient pressure variation for a pulse excited annular ring and annular cylindrical array are shown in Figures 5.9 and 5.10 respectively.

The overall conclusions drawn from the results obtained are as follows:
Performance evaluation of the annular ring and annular cylindrical array shows that the sidelobe levels and 3dB beamwidths remain unaffected for radii greater than 40\(\lambda\). The evaluation of the effective acoustic pressures of the annular ring and annular cylindrical arrays show a very good focusing effect compared to the linear array.

The axial pressure distribution of the proposed arrays have been investigated for different array configurations from which the number of elements and array geometry can be optimised for different pipeline geometry. A good focusing effect can be obtained by optimizing the number of elements and the radius of the annular ring and annular cylindrical arrays. The transient response of the pulse excited annular ring and annular cylindrical arrays over the contours of the test pipeline have been evaluated.

Transducer elements have been fabricated using PVDF as the active, mild steel as the backing and conducting silver preparation as the bonding materials. The transducer is operated in the (3,3) mode. The design considerations and calibration of these transducers are discussed in the appendix. Though single transducer elements have been constructed successfully, arrays could not be fabricated due to technical limitations. The construction of a high frequency array is comparatively complicated. The interelement spacing between the transducer elements becomes considerably small when high frequencies are considered. It becomes very difficult to construct the transducer manually. The electrode connections to the elements can produce significant loading effect. The array has to be fabricated using hybrid construction techniques. The active material has to be deposited on a proper substrate and etching techniques are required to fabricate the array.
6.2 SCOPE FOR FURTHER WORK

Theoretical models of an annular ring array and an annular cylindrical array have been developed for inspection of underwater pipelines. Performance evaluation of these models have been carried out and the various array parameters have been optimised. With sophisticated fabrication techniques the annular ring and annular cylindrical arrays can be constructed based on the theoretical models developed and taking the effects due to the finite size of the array elements into consideration. Ultrasonic nondestructive testing techniques can be extended to biomedical fields as well. These days, focused ultrasound is also being considered in biomedical applications like hyperthermia treatment for cancer. The focused ultrasonic beam is directed to the affected part. The ultrasound treatment is comparatively less harmful than other radiations. The annular ring, annular cylindrical or other similar structural forms of arrays may also find applications in the near future in treatments where curved contours of the human body are affected.