Recent Developments in Air-Coupled Ultrasonic Capacitive Transducers for use with NDE experiments

Craig S McIntyre¹, David A Hutchins¹ and David W Schindel²

¹Dept. of Engineering, University of Warwick, Coventry CV4 7AL England, UK
²Institute for Aerospace Research, N.R.C., Montreal Road, Ottawa, Ontario, K1A OR6, Canada

Abstract: A new design of air-coupled capacitive ultrasonic transducer has been developed that could have potential use in NDE experiments particularly when the pulse-echo method is employed. The design is based on a standard capacitive transducer [1], except the newly developed device has two concentric, backplate elements underneath a common metallic membrane. Each of the backplate elements are electrically isolated from one another allowing one to be used as a source of ultrasound, whilst the other is utilised as a detector. This yields a device containing both a source and receiver of ultrasound within the same structure. Experiments have shown that device performance depends on which element is selected to be the source and which to be the receiver, surface roughness of the backplates, membrane used and size of bias voltage used. Initial studies have shown that the device is capable of detecting the front face echo from material samples such as Aluminium and perspex.

INTRODUCTION

NDE (Non-destructive evaluation) is a useful technique in measuring and analysing materials used in science and engineering. Air-coupled ultrasonic transducers can be employed as the instruments of NDE and one of the main configurations they are used in, is the pulse-echo system. This is where a transducer will emit an ultrasonic pulse into the sample, via a coupling medium (air in this case), and attempt to detect the echo from the material sample. The pulse-echo technique is used when it is difficult to gain access to both sides of the material sample and ideally it is the same device that emits the pulse and detects the echo. If you were to use the same capacitive device, then you have a problem in that the large excitation pulse required by the source to drive it into oscillation has to be de-coupled from the receiver to avoid damaging the receiver amplifier circuitry. This can be done by either having some extra de-coupling switching circuitry between source and receiver circuits or by physically separating the two elements used as the source and receiver. This paper details a device where the latter approach was adopted.

TRANSUCER DESIGN AND TESTING

The transducer was fabricated using a brass rod as the central conductor placed inside a collection of concentric, cylindrical shapes alternating between electrical insulator and conductor (see figure 1). The whole structure was then pressed together. One face of the structure was machined flat to form the active area of the device over which the common membrane would be placed. Both the central and outer electrodes were then polished. In order to minimise any noise due to ‘cross-talk’ between the two elements the structure also contained an earth ring isolated from the two conducting elements by an insulating layer on either side. The leads used for connection to the device were a pair of shielded miniature BNC leads (one for each electrode)

![Diagram of the transducer design](image)

FIGURE 1. Schematic layout of the twin axial capacitive ultrasonic transducer
The transducer was then calibrated by using a separate capacitive transducer, firstly as a source to determine the characteristics when either the central or outer electrode was used as a receiver. Then a separate capacitive transducer was used as a receiver to capture the device response when either the central or outer electrode was used as a source. The response of the device was best when the central electrode was used as the source, with the outer element as the receiver and the results are summarised by the table below.

**TABLE 1. Summary of results from characterising device response**

<table>
<thead>
<tr>
<th>Element used as Source (S) or Receiver (R)</th>
<th>signal amplitude (in mV)</th>
<th>Bandwidth (in MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central S</td>
<td>260</td>
<td>1</td>
</tr>
<tr>
<td>Central R</td>
<td>25</td>
<td>0.6</td>
</tr>
<tr>
<td>Outer S</td>
<td>37</td>
<td>0.7</td>
</tr>
<tr>
<td>Outer R</td>
<td>310</td>
<td>0.68</td>
</tr>
</tbody>
</table>

**PULSE-ECHO EXPERIMENT RESULTS**

Some initial studies were carried out using the device in a pulse-echo configuration, using the central electrode as a source, with 150V bias, driven by a Panametrics pulser and the outer electrode as a receiver, with 100V bias, connected to a Cooknell charge amplifier (this was a similar system to the one that generated the device response results shown in the previous section). The source bias was de-coupled from the pulser unit. Varying samples were used including Aluminium and Perspex. In the figure below, the front wall echoes can clearly be seen from the transducer response in pulse echo mode, when a Aluminium sheet is placed 40 mm away in air.

**FIGURE 2.** Typical waveform detected by the transducer in pulse echo mode (centre = source, outer = receiver)

**CONCLUSIONS/APPLICATIONS**

From the initial experiments conducted it was observed that the device performance depended upon the backplate roughness of the and membrane material used (in common with other capacitive devices). The choice of electrode employed as source and receiver when the device was operated in pulse-echo mode was also important. The results from the device so far look promising and it is hoped that the device could be developed into a useful inspection tool for NDE applications.

**ACKNOWLEDGEMENTS**

This work was funded by an EPSRC CASE award in conjunction with BG (British Gas)

**REFERENCES**


748