Modelling and Parameters Study of Piezoceramic Parts of an Electroacoustic Transducers

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Electroacoustic transducers as transmitters and receivers play major role in underwater communication systems. Piezoceramic rings are the most important parts of electroacoustic transducers. In this investigation, attempts were made to use the matrix model and the finite element model to evaluate frequency behaviour of piezoceramic rings. In order to validate the accuracy of the proposed models and the solution algorithm, results obtained from both models were compared with experimental results presented by Radmanović, et al. Upon confirmation of the obtained results from the two models, the effects of the geometrical parameters on the frequency response of the ring and the surrounding domain in which the ring oscillates were studied. Based on the obtained results, the geometrical parameters have effects on both the frequency resonance of the ring, as well as the value of the electrical impedance. It is also noted that the surrounding domain only causes change on the intensity of the ring's electrical impedance.

1. INTRODUCTION

The use of acoustic waves for the recognition and location identification of underwater bodies is called sonar.[1–3] Compared to the other form of wave transmission, acoustic waves are more suitable for underwater applications due to low attenuation.[3–5] Consequently, underwater applications of sonar are related to acoustic fundamentals. Due to military needs, especially during world wars, the related technologies associated with sonar have developed.[6] A transducer is a device capable of converting one form of energy into another.[7] The underwater transducers convert electric energy into a sound wave, which is mechanical energy, and vice versa.[6,8] Careful design and modelling of transducers is necessary, since it is crucial that they perform at the desired level. Moreover, recognition of the frequency behaviour of piezoceramic rings has high importance, since they are the main parts of transducers. The frequency behaviour of a piezoceramic ring is usually obtained by studying its impedance curve and calculating its resonance frequencies.[9]

Traditionally, the design of transducers and the study of the behaviour of their parts, particularly piezoceramic rings, has been done by using lumped parameters models. These models were made on the principle that by assuming one dimension, their different parts could be modelled as a group of masses connected by several springs and dampers.[6,10] Since it is possible to equate mechanical parts with the forming elements of an electric circuit, the next step in modelling is to use equivalent circuits. Through using these circuits, the desired parameters for performance analysis, such as frequency resonance, bandwidth, etc., would be obtained.[11] Another analytical model that can be used is the 2D matrix model. In this model, the relations of forces acting on surfaces, different surface velocities, voltage, and current of a piece like a piezoceramic ring would be expressed in the form of a matrix relation and an impedance matrix of 5*5. This model is also capable of considering the effects of the acoustic environment. For parts like metal rings not containing voltage and current, the size of impedance matrix would be reduced to 4*4.[12,13] Since it was not possible to use analytical models to analyse transducers with complex geometries, finite element methods have been used for the design and analysis of these transducers. So, the main advantages of finite element analysis is the possibility of precise and complete modelling of all parts with complex geometries.[14,15]

In light of the points discussed, the present study utilizes matrix models as well as finite element models, and applies them to simulate a piezoceramic ring. These models can be considered advanced methods in the modelling of the electroacoustic transducers parts. In order to validate the used algorithm, initially for a specified piezoceramic ring, the obtained frequency response was compared to valid results presented by experimental studies in credible references. Then, the frequency response of a piezoceramic ring for several dimensional conditions and different environments were studied. Finally, by interpreting these results through analytical models, fundamentals of vibrations, and circuit analysis, the effects of different parameters on the considered frequency response was evaluated.

2. METHODS OF MODELLING PIEZOCERAMIC RINGS

The design and modelling of underwater transducers is possible through the recognition of piezoceramic rings' behaviour