Structural Analysis and Modeling of Tonpilz MEMS Acoustic Transmitter for High Power Imaging System

S. Suresh, S. Anbuarasan, M. Balachandhar

Abstract -- Imaging System requires High Power Transmitter with reduced weight. We carry out the design of Acoustic Transmitter. Since miniaturization in the field of sensors and transducer is rapid, a MEMS acoustic transmitter is designed. The transmitter along with the structural analysis and modeling has done by Intellisuite for the tonpilz type design, where PZT Sol gel is used as active material. The simulation studies are done by varying the head mass, tail mass and length of the active material. This transmitter is suitable for the underwater target detection, object classification and localization, sub bottom profiling and ocean topography applications. The proof of concept of Tonpilz type acoustic transmitter is achieved in this work.

Keywords: Intellisuite, PSPICE, Piezoceramic transducer, Tonpilz, Equivalentcircuit, Radial vibration

I. INTRODUCTION

Environment is the new frontier for major future discovery for the benefits of the world at large. The vastness of the oceans mirrored the vast potentials that lie beneath it. In order for scientist and researchers to explore these vast resources, newer and better sensing technology is pertinent. Of course, any sensor module would not be of any use if there are no reliable platforms to take them to the bottom of the oceans or any water column. Currently. The research into producing acceptable sensor system/modules will require close international collaborations. The whole range of potential measurement and sensing requirements also may disrupt the proper development of a robust and reliable sensing system/module. Underwater sensor technology can be divided into the acoustic or non-acoustic based sensing. The major problem of acoustic-based sensors is that they are very prone to noise. Because acoustic signal are mechanically-actuated signal, the dynamic nature of the underwater medium disrupts the signal quality. On the other hand, the non-acoustic sensors are very application-specific, and must be tailored made for specific applications. The utilizations of MEMs-based underwater sensor system are a major future scope of research. MEMs-based sensor will optimize the cost of material and energy.

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Piezoceramic compositions are engineered to produce high density microstructures for improved electrical and mechanical properties. On an international basis, it is usual to divide piezo ceramics into two groups. The antonyms soft and hard doped piezoelectric ceramics refer to the ferroelectric properties, the mobility of the dipoles or domains and hence also to the polarization / depolarization behavior. Soft doped piezo ceramics are characterized by comparatively high domain mobility and a resulting doped PZT materials can be subjected to high electrical and mechanical stresses. The stability of their properties destines them for high-power applications.Several types of piezoelectric ceramic materials are available. Each type istailored towards the requirements of particular applications. This is achieved bychanging the chemical composition of the ceramic to enhance specificproperties. The ceramic materials are arranged in three groups such as Hard Materials,Soft Materials and Custom Materials. This material is ideally suited for ultrasonic cleaning, sonar, and other high poweracoustic radiation applications. PZT400 Series is a Lead ZirconateTitanatematerialcapable of producing large mechanical drive amplitudes while maintaining lowmechanical and dielectric losses. In addition, it can be used under both constantand repetitive conditions.

$$S=S^{T}.T+D.E$$

$$D=d.T+\frac{D}{\varepsilon^{T}}$$

$$E=-g.T+\frac{D}{\varepsilon^{T}}$$

$$S=S^{D}.T+g.D$$

$$d=\varepsilon_{r}\varepsilon_{o}.g$$

II. DESIGN OF TRANSDUCER

The tonpilz transducer is most often used for the acoustic transducer inside itself Qudripode and Tripode. Before considering the design different kinds of the material are discussed .in this proposed project considering the piezoceramic and Magnetostrictive material for the designing of the acoustic transducer. The term tonpilz or "acoustic mushroom" may refer to a certain type of underwater electro-acoustic transducer. By sandwiching the active materials between a light, stiff radiating head mass and a heavy tail mass, the transducer can effectively operate as either a projector (source) or a hydrophone (underwater acoustic receiver). In this work mild steel is used as tail mass and aluminium is used as head mass where PZT (lead zircon tetitanate) Piezoceramic transducer.

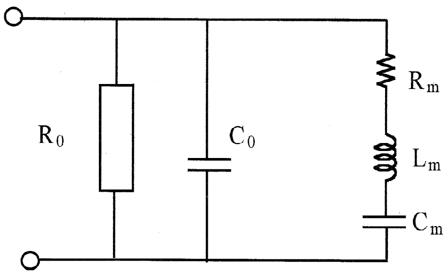

Fig.1 Equivalent circuit

$$Co = \frac{n^2 A_c \varepsilon^T_{33}(1-k_{33}^2)}{l},$$

$$C = \frac{S^E_{33} l}{A_c},$$

$$L = \rho A_a$$

$$C = 1/(Z_a v_a)$$

$$Z_a = \rho v_a A_a$$

$$R = \omega \rho A_a \delta_m$$

III. MODELING

Intellisuite is a tightly integrated design environment that will link your entire MEMS organization together. Built to scale from a point tool to an organization-wide tool, Intellisuite unifies various engineering and manufacturing tasks into a single living design environment. In this design a tonpilz design is carried out for the geomantic model by considering the design a high power compact and economically feasible transducer is designed where the active material used here is PZT(Lead ZirconateTitanate). And the design is tested for various sizes of head mass and tail mass here we have 50μmdia and 10μm,active material of about 30μmdia and 100μmprobable the head mass of 70μmdia.where the material for the tail mass and head mass is mild steel and aluminum respectively. Further precedence of the efficient type transducer can be modeled by using different materials for head mass tail mass and the active material.

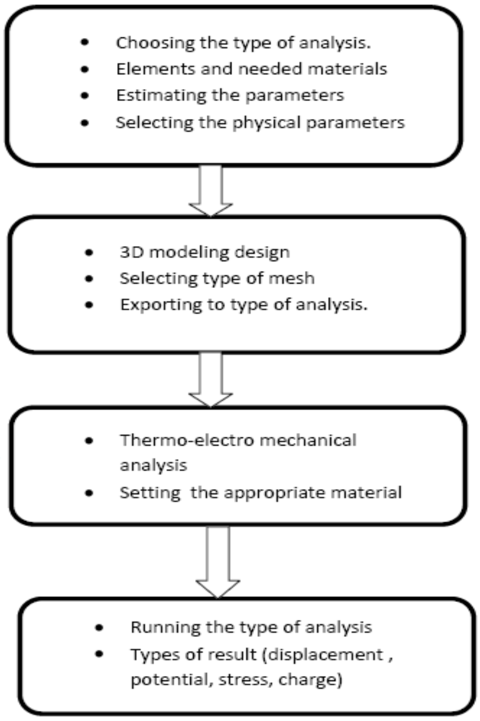

Fig. 2.Intellisuite modelling procedure

IV. DEVICE DESCRIPTION AND ISSUES

A cross-section of the 14 kHz tonpilz device studied is shown in along with the simplest spring-mass idealization. The device consists of a stack of four PZT4 ring transducer elements connected electrically in parallel, a steel tail mass, a flared aluminum head mass, a steel compression bolt, and a foam matching layer bonded to the head mass. Sphere volume in the spring-mass model indicates relative lumped mass of the tail, head, and matching layer for the device. The tonpilz unit had been in production for many years, and design rules for the device died with the designer. This study was prompted by replacement of the original foam matching layer material, which had gone out of production, with a newer, more robust Foam material. Prototype devices with the new foam gave considerably lower output than older devices. Empirical trials and 1D simulation had failed to improve device performance. Therefore, finite element modeling was employed to better understand performance issues and identify potential design improvements.

Model results are compared to measurements of electrical impedance, pressure, and surface displacement patterns. Correlation between experiments and PZFlex time domain finite element models [6] is generally good. In particular, responses are quite sensitive to longitudinal and shear wave absorptions in the matching layer. This study reveals practical details of an air-coupled tonpilz's 3D modal response and sensitivity to mounting (boundary) conditions. Finite element modeling provides the physical insight missing from simple 1D model and helped interpret confusing experimental data.

The proposed the cylindrical radial composite piezoelectric ceramic transducer is presented and studied. The transducer consists of an inner radially polarized piezoelectric ceramic thin-walled circular tube and an outer metal thin-walled cylindrical shell which are composed in the radial direction. The radial vibrations of a metal thin-walled cylindrical shell and a piezoelectric ceramic thin-walled circular tube are analyzed. Their radial electro-mechanical equivalent circuits are obtained. Based on the equivalent circuits and the radial boundary conditions, the composite electro-mechanical equivalent circuit of a cylindrical radial composite piezoelectric ceramic transducer is obtained, the resonance frequency and anti-resonance frequency equations of the cylindrical radial composite piezoelectric transducer are derived. Then the relationship between the resonance frequency, the anti-resonance frequency, the effective electromechanical coupling coefficient and the geometrical dimensions of the cylindrical radial composite piezoelectric ceramic transducer is analyzed. It is illustrated that the resonance frequencies and the anti-resonance frequencies from the frequency equations are in a good agreement with that of the experimental results[2]. This design tested for all possible head and tail mass .the experimental results shows various design of the tonpilz transducers are verified.

V. RESULT

The modeling design procedure is analyzed through the Intellisuite software for constructing a acoustic transducer and in that transducer namely tonpilz model .The transmitting current for various head mass diameters is to be analyzed and from that the best offering of the radiating head mass is to be identified and in that the fundamental resonance frequency and the peak value will be identified and by the way the current response for the resonance frequency and peak value to be derived. Thus the Piezoceramic rod in the tonpilz transducer will be replaced by Piezoceramic material and another Piezoceramic, therefore then the model should be undergo the various parameters testing like transmitting current response, voltage response and beam pattern analysis. The analysis is tested for different dimension of the head mass tail mass additionally tested for different dimension for the Piezoceramic material namely cylindrical, cylindrical tube and cylindrical multi tubes

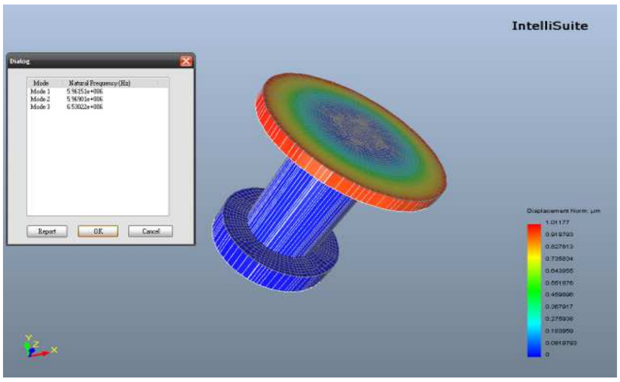

Fig.3. Electromechanical displacement analysis result of cylindrical with head mass 70μm

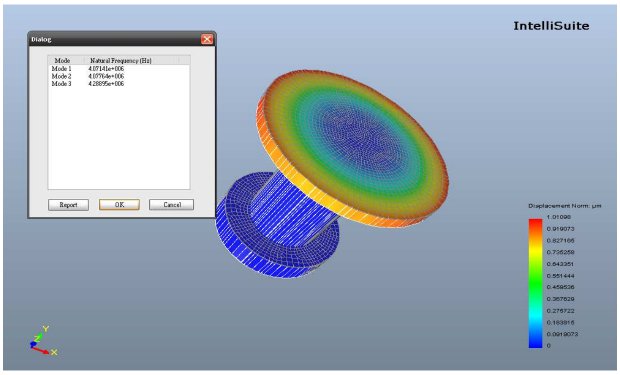

Fig.4. Acoustic Transmitter with 80μm Head Mass Cylinder type

VI.CONCLUSION

A high power acoustic transducer has been proposed to design for the power of 2-4kW, 2-16 MHz using the Intellisuite software .design and modeling has been planned to carry out by varying the dimensions of the radiating face.Thus the optimized high power, compact and low-frequency broadband design is to be identified. The transducer will show a broadband behavior as per expectation but the performance needs are still yet to improvedfor the further enhancement in the field of ocean application. This modeling and optimization need to be further proceeded for a better frequency range.

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