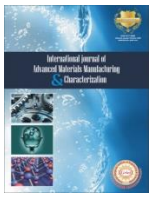

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Effect of Poisons Ratio on The Modal Analysis of Pzt Discs For Uniaxially Loaded Energy Harvesters

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A B S T R A C T

This paper presents the effect of poisons ration on the modal analysis of PZT-4, PZT-5A, PZT-5H and PZT-8 discs at different poisons ratios such as 0.21, 0.31 and 0.41. Poisons ratio is 0.31 for all piezoelectric materials. Therefore first at 0.31 poisons ratio the natural frequencies at different modes of the above mentioned PZTs are studied. And also studied the effect of poisons ratio on the natural frequencies of PZT. The dimensions of PZT disc are 32 mm diameter and 2mm thickness. Simulation tool (Ansys 14.5) have been used for studying the modal analysis of the PZT discs by considering undamped condition. For PZT-5A, PZT-5H and PZT-8,the maximum deformation 26.776 µm is occurred at the mode 6 . For PZT-4, maximum deformation is 26.56 µm.

*Keywords:*Modal analysis; PZT;Poisons ratio; Natural frequencies.

1. INTRODUCTION

Lead Zirconate Titanate Pb ($Zr_{(1-x)}$ Ti $_x$) O_3 is a material that is known for its high piezoelectric and ferroelectric properties. Thick and thin films of lead zirconate titanate(PZT) have been repeatedly used in a variety of piezoelectricity or piezo-resistivity based sensors such as bio sensing cantilevers[1] and pressure sensors[2]. PZTs are used for electric energy harvesting and sensing purposes[3]. There are different types of PZTs are available in the market such as PZT-4, PZT-5A, PZT-5H and PZT-8. Piezo electricity is a form of coupling between the mechanical and the electrical behaviors of ceramics and crystals belonging to certain classes. These materials exhibit the piezoelectric effect, which is historically divided into two phenomena as the direct and the converse piezoelectric effects. When a piezoelectric material is mechanically strained, electric polarization that is proportional to the applied strain is produced. This is called the direct piezoelectric effect and it was discovered by the Curie brothers in 1880.When the same material is subjected to an electric polarization, it becomes strained and the amount of strain is proportional to the polarizing field. This is called the converse piezoelectric effect or inverse piezoelectric effect. In recent times researchers are using PZTs for electric generation purposes in the place of batteries by using impact loads on the pzt circular discs and developing energy harvesters. Before applying the impact loads on the pzt discs, the natural frequencies of PZT discs must be known. The natural frequencies of those discs can be studied by modal analysis. A modal analysis calculates the frequency modes or natural frequencies of a given system, but not necessarily its full-time history response to a given input. The natural frequency of a system is dependent only on the stiffness of the structure and the mass which participates with the structure. It is not dependent on the load function. In this paper modal analysis of PZTs are studied at different poisons ratios and their effect to modal frequencies. Figure 1 shows the actual PZT-5H disc with electrodes.

2. SIMULATION

The dimensions of PZT discs are 32 mm diameter and 2 mm thickness. Simulation was carried out by considering the dimensions of all discs are kept constant. From figure 2- 7 shows the mode shapes of PZT-8 type disc. Even though the values of modal frequencies are different from type of disc to disc but mode shapes of all the discs are same. PZT-8 disc is the

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best type of disc for using the energy harvesting purpose as compared to other types operating at high frequencies, therefore, the mode shapes are shown only for PZT-8 disc. The properties of PZTs are taken from Morgan Piezoceramics Ltd data book. Simulation was conducted in Ansys 14.5 by considering the PZT is an isotropic material. Mode 1 is occurred at the frequency of 13.75 kHz, mode 2 is generated at 27.678 kHz, mode 3 is at 27.686 kHz, mode 4 is at 43.779kHz, mode 5 is at 43.834 kHz and mode 6 is occurred at 49.576 kHz. The maximum deformation is taken place at the center of the pzt discs in the case of mode 1 and mode 6, therefore, mode 1 and mode 6 are conducive for operating uniaxial impact loaded energy harvesters to generate maximum power. The study of modal analysis of pzt discs have been done at six mode shapes of each disc. Total mode shapes are 24 at the poisons ratio of 0.31 and 18 mode shapes are studied at poisons ratios 0.21, 0.31 and 0.41.

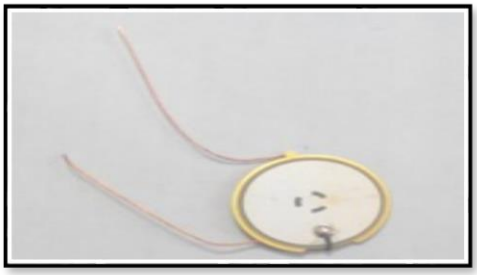

Figure 1: PZT-5H disc with electrodes

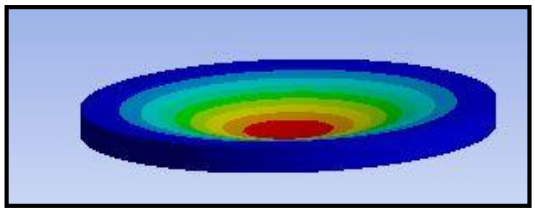

Figure 2 :PZT -8's Mode 1

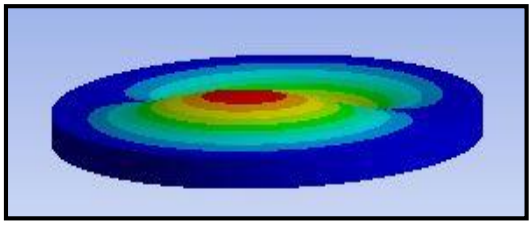

Figure 3 : PZT -8's Mode 2

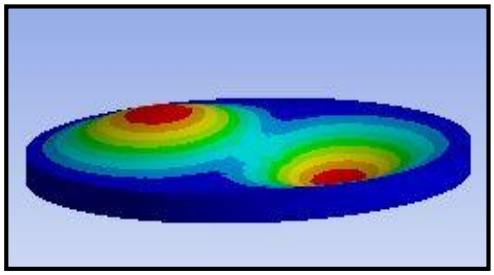

Figure 4 : PZT -8's Mode 3

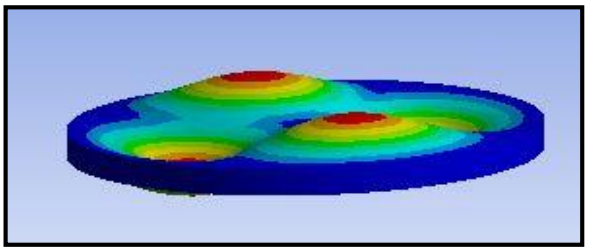

Figure 5: PZT -8's Mode 4

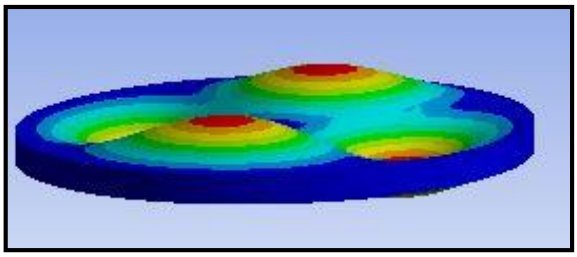

Figure 6: PZT -8's Mode 5

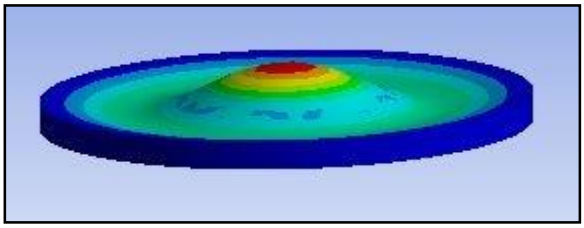

Figure7: PZT -8's Mode 6

3. RESULTS AND DISCUSSION

A mode is a combination of a deformed shape in which the structure will exchange kinetic-energy and stain-energy continuously, and the natural frequency at which the mode shape occurs. If only one mode is present, in the un-deformed state, the velocity at every point will be at its maximum. At this time, the kinetic energy is at its peak and the strain energy is zero, at the maximum deformed state, the instantaneous velocity is zero. The kinetic energy at this point is zero while the strain energy is at a maximum. Another important point to remember is that there are multiple modes for a structure. Each mode shape occurs at a very specific frequency called the natural frequency of the mode in question. It is entirely possible for a structure to have multiple modes at the same frequency. An example is a beam with a symmetrical cross-section, clamped at one end: The first two bending mode shapes will be at the same frequency. However, the mode-shape will be in different planes. Note also that, because the system is linear, the superposition principal holds: Each mode's behavior can be solved separately. The total displacement due to all modes being present will be the sum of the results due to each mode. Each mode shape oscillates at the natural frequency of that mode. In other words, multiple modes, each at their own natural frequency will be present in the results.

Figure 8 describes the modal frequencies of PZT-4, PZT-5A, PZT-5H and PZT-8 at different modes. For PZT-8 , the mode shapes are occurred at the frequencies of 13.75kHz, 27.678 kHz, 27.686kHz, 43.779kHz, 43.834kHz and 47.576kHz which are the highest values when compared to the modal frequencies of PZT-4, PZT-5A and PZT-5H. The poisons ratio for all piezo ceramics is 0.31. That is why initially the modal analysis of all pzt discs are studied at that poisons ratio. For PZT-8 disc the values of modal frequencies are high, however, the effect of poisons ratio on modal analysis is studied, which shows the figure 9. It indicates the proportionality varying of the values of modal frequencies in relation to poisons ratio.

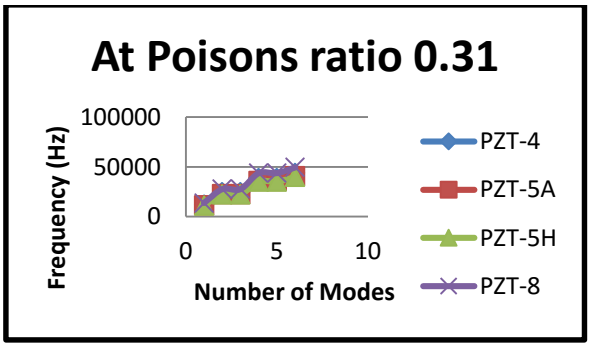

Figure 8 : At poisons ratio 0.31 modal frequencies of different PZTs

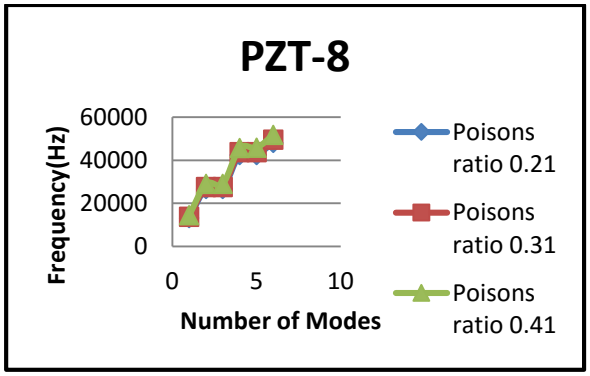

Figure 9: Modal frequencies of PZT-8 disc at different poisons ratios

Figure 10 presents the deformation values of PZTs at the modal frequencies. It is observed in simulation that there is no change in the values of deformation in the cases of PZT-5A, PZT-5H and PZT-8, however, modal frequencies are different. The maximum deformation is occurred at the mode-6 i.e., 26.776 µm. For PZT-4, maximum deformation is 26.56 µm.

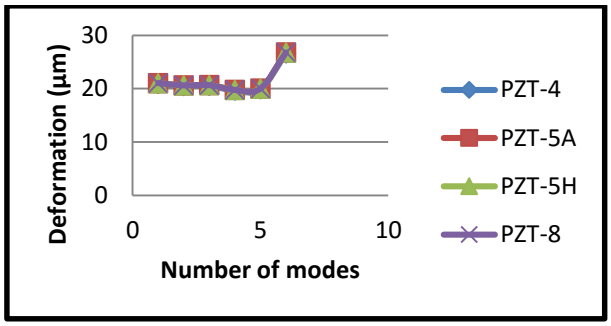

Figure 10:Deformation of different PZTs at 0.31 poisons ratio

4. CONCLUSIONS

The modal analysis of discs PZT-4, PZT-5A, PZT-5H and PZT-8 is studied by using Ansys 14.5. Proportionality effect of poisons ratio to modal frequencies of pzt discs is demonstrated. After studying the dynamic behavior of pzts, PZT-8 type disc is displayed the high natural frequencies in compared to other types. Therefore PZT-8 type disc can also be used for energy harvesting purposes which operates at high frequencies for charging the low power devices.

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