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Development of a Novel Optical Fiber Hydrophone Sensor for Marine Applications

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***Abstract:** A critical area of research is to improve the sensitivity of the mandrel and to identify the target. In our earlier work, we have simulated our design using ANSYS tool and calculated the sensitivity of the mandrel. In this paper, we have two phases of work, one is the continuation of the previous work, the design has been finalized the design for higher sensitivity and the same design has been fabricated and the various steps of fabrication process involved in developing the hydrophone is shown. In the second phase of the work, signal analysis has been carried out using MATLAB. From the obtained results the behavior of the signal for the detection and finding the source target using sound waves has been done.*

***Index Terms:** Hydrophone, Mandrel, Ansys Tool, Sensitivity, Fiber Optic Hydrophone.*

I. INTRODUCTION

In recent years, a significant amount of improvement has happened in the design of hydrophones for various naval applications. Numerous demonstrations of hydrophone technology have taken place in a towed array, fixed ocean, Arctic and acoustic environments.

Mandrel based Hydrophone technology is considered as an alternative technique to conventional hydrophones for numerous applications like measurement of acoustic pressure and tracking the drivers, etc. Since the last decade, there have been different types of demonstrations in which hydrophones produced the same results and sometimes showed remarkable performance when compared to conventional hydrophones in real test environments. The selection of hydrophones for a given application depends upon the required dynamic range, sensitivity, and operational environment.The hydrophones consist of Mandrel design which has undergone field tests. Firstly, the hydrophones were used to measure acoustic signals to predict the source of the target. According to the previous study field test results, the mandrel was considered to be the best option for this application.

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Secondly, the mandrel is constructed with multiple materials and dimensions, because of this, we can change the dimensions or thickness of the materials used, to increase the sensitivity. Many researchers have identified that it is easier to remove undesirable resonances in mandrel structures than in other structures.

The sensitivity of Mandrel or hydrophone depends on two factors:

1. The composite material used to construct the device.
2. The length of optical fiber used to wrap around it.

Adding to the above two factors, the sensitivity can be increased if the air is incorporated into the mandrel design. Normally, mandrel or hydrophone reacts to an acoustic source of the signal, due to the deformation of the laser light in the optical fiber, stretching or compressing the optical fiber is proportional to the applied pressure. Based on this, sensitivity may be measured by using a Michelson interferometer configuration rather than using a Mach-Zehnder configuration, or by using a push-pull design in both arms of the interferometer. If we use any of these methods it will increase sensitivity by 6dB.

Non-mandrel hydrophones like prolate spheroids, coated fiber, and flexural disks are also involved effectively with optical fiber which is contacted to a compliant medium, thus the sensitivity of all these devices is based upon the above factors of mandrels or hydrophones. Whereas, in the Fabry-Perot diaphragm type, the mandrel sensitivity fully depends on the nature of the materials used for construction and not interacting with optical fiber length. The field-tested hydrophones having mandrels are constructed either by using air blocked plastic, solid plastic or of metal. [2].

II. RELATED WORK

The advantages of Fiber optic hydrophones are compactness, flexibility, grating structure as compared to conventional piezoelectric transducers. Hence these mandrel or hydrophones are used for surveillance in the acoustic environment.

The two broad categories of Fiber optic hydrophones are

(a) Fiber mandrel hydrophones
(b) Distributed Feed-Back Fiber laser (DFBFL) hydrophones

The mandrel or hydrophones made of fiber (Interferometric hydrophones) consists of two mandrels. One was used to sense a signal in the acoustic environment and the second may be placed in the acoustic environment without being exposed to pressure or it can be placed away from the water because the second mandrel acts as a reference. Since the fiber used here, the total length changes while winding on the mandrel. This was due to the expansion or contraction of the sensing mandrel when pressure is applied upon acoustic mandrel. [3].

Optical fiber sensing methods are listed below. [1]

1 Optical Fiber Devices
2 Single Fiber Sensors
3 Fiber-Optic Interferometers
  a. Michelson Interferometers
  b. Mach-Zehnder Interferometers
  c. Fabry-Perot Interferometers
  d. Sagnac Interferometers
4 Fiber Bragg Gratings (FBG's).

III. DESIGNING AND IMPLEMENTATION OF MANDREL USING ANSYS TOOL

The mandrel was designed by using the ANSYS tool. The analytical values show an improvement in sensitivity. So the same values have been finalized for the fabrication. The following figures show how the design process takes place.

Step 1- Designing of Mandrel

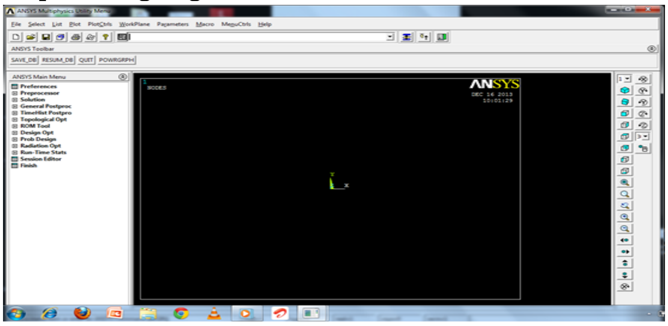

Fig 1: Initial step

Step 2 – Creating a Mandrel Segment &Meshing of design

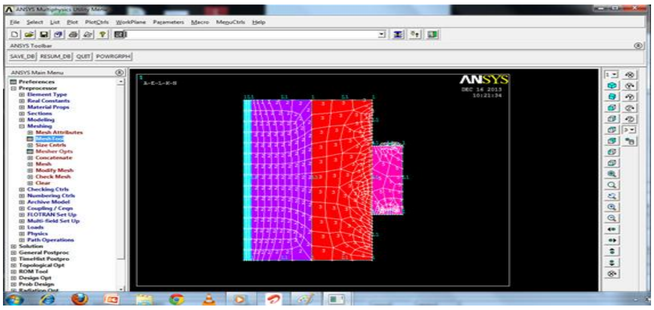

Fig 2: Represents the meshing of the mandrel for the designed mandrel

Step 3 –Applying pressure

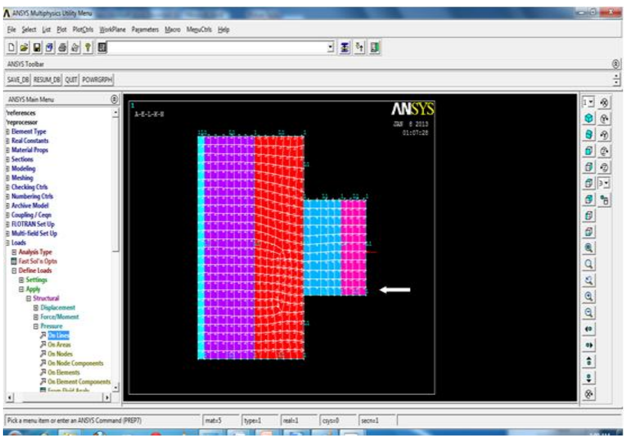

Fig 3: Pressure Applied in the Meshing

Figure 3 represents the changes in the dimension of the mandrel with applied pressure.

Step 4 - Designed Mandrel

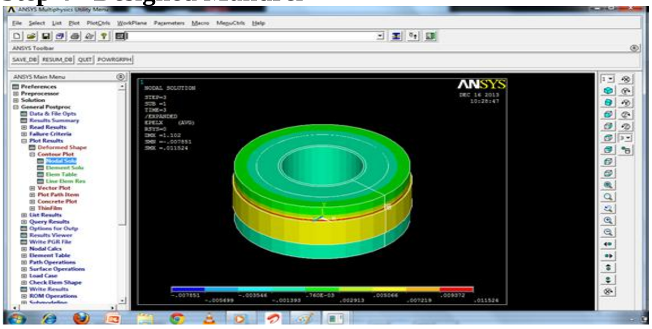

Figure 4: Full view of radial strain

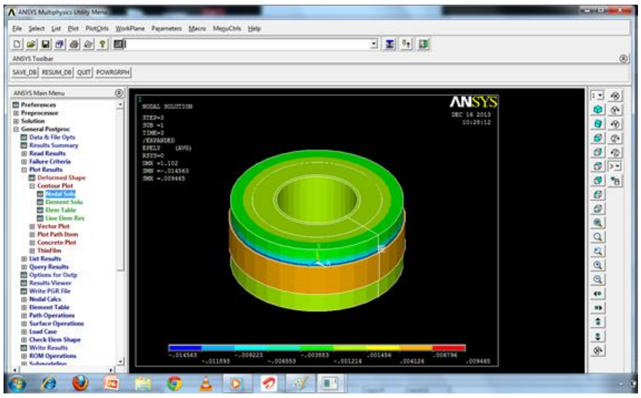

Figure 5: Full view of axial strain.

Figure 4 and 5 represents the full view of radial and axial strain of the designed mandrel.

IV. RESULTS AND DISCUSSIONS

In this section, we have written the MATLAB code to analyze the signal for varying input signals with different phase changes as shown below. Output 1 represents a bit of noise when the filter is used. The noises are removed and the signal is displayed. Based on these inputs the source of the signal with distance can be calculated. This has been done for our in-house generated random values.

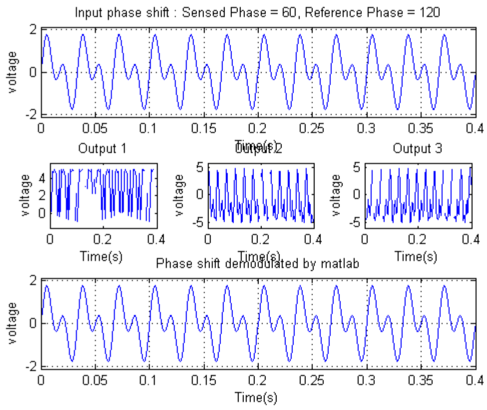

Fig 6: Signal Obtained from MATLAB for a Phase shift of 60 degrees

Figure 6 shows a case when the reference signal is 120 degree and the input sensing signal is 60 degree then the value keep changes in the output signal.

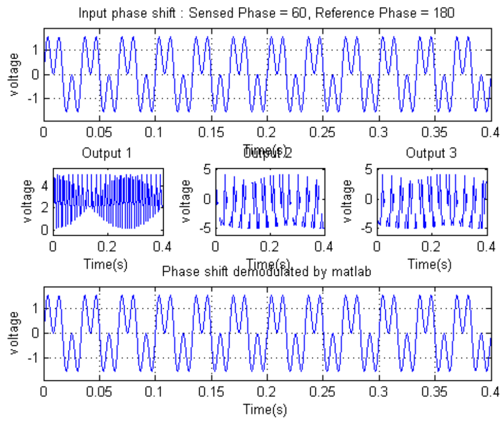

Fig 7: Signal Obtained from MATLAB for a Phase shift of 120 degrees.

Figure 7 shows a case when the reference signal is 180 degree and the input sensing signal is 60 degree then the value keep changes in the output signal.

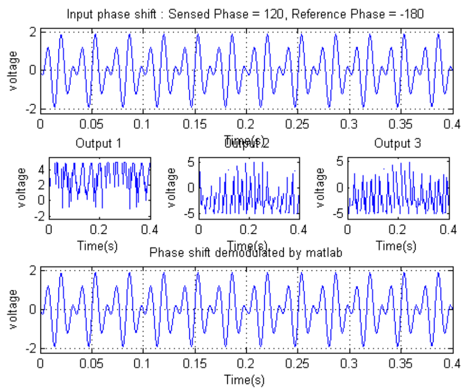

Fig 8: Signal Obtained from MATLAB for a Phase shift of 60 degrees.

Figure 8 shows a case when the reference signal is 180 degree and the input sensing signal is 120 degree then the value keep changes in the output signal.

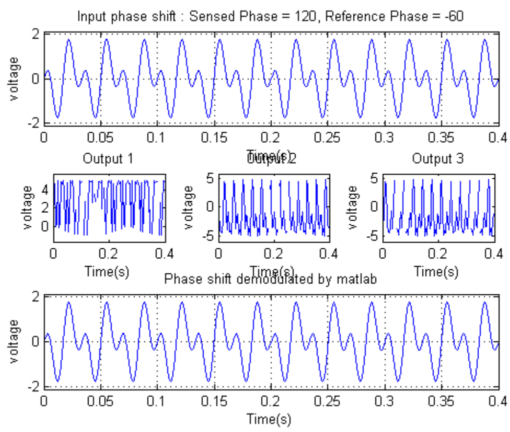

Fig 9: Signal Obtained from MATLAB for a Phase shift of -60 degree.

Figure 9 shows a case when the reference signal is 60degree and the input sensing signal is 120 degree then the value keep changes in the output signal.

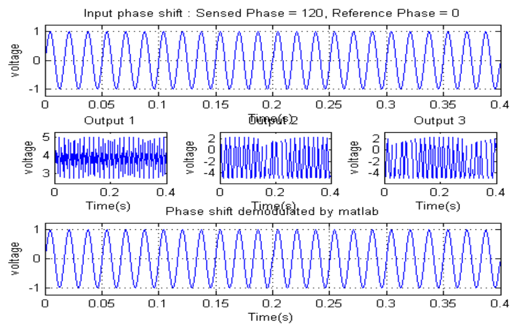

Fig 10: Signal Obtained from MATLAB for a Phase shift of 120degrees.

Figure 10 shows a case when the reference signal is 0 degree and the input sensing signal is 120 degree then the value keep changes in the output signal.

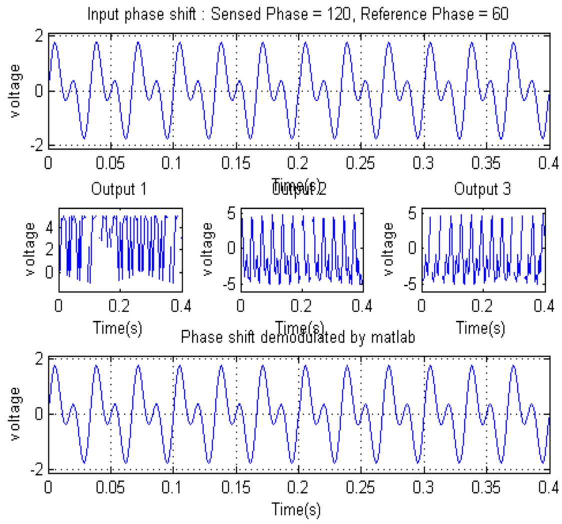

Fig 11: Signal Obtained from MATLAB for a Phase shift of 60 degrees.

Figure 11 shows a case the reference signal is 60 degree and the input sensing signal is 120 degree then the value keep changes in the output signal.

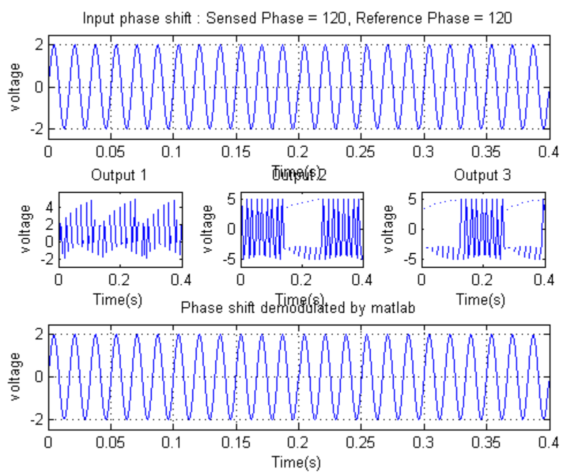

Fig 12: Signal Obtained from MATLAB for a Phase shift of 0 degrees.

Figure 12 shows a case when the reference signal is 120 degree and the input sensing signal is 120 degree then the value keep changes in the output signal.

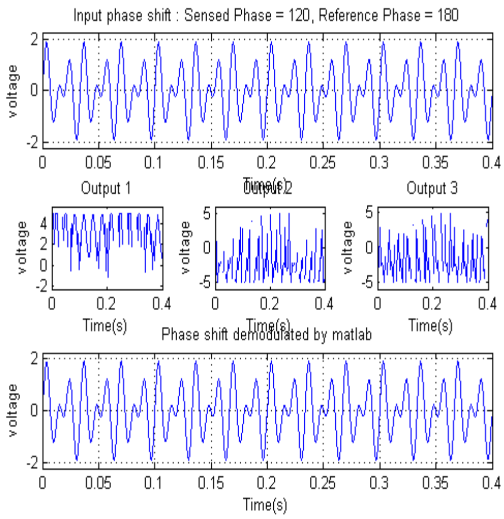

Fig 13: Signal Obtained from MATLAB for a Phase shift of 60 degrees.

Figure 13 shows a case when the reference signal is 180 degree and the input sensing signal is 120 degree then the value keep changes in the output signal.

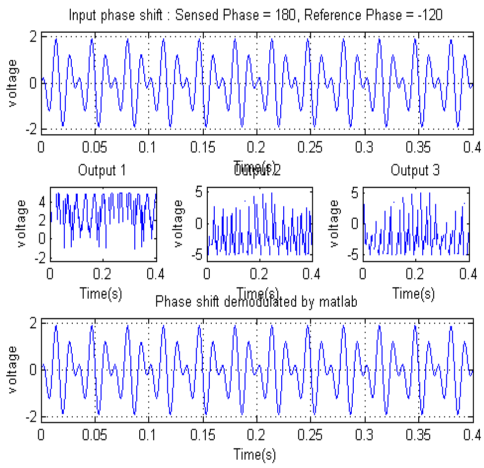

Fig 14: Signal Obtained from MATLAB for a Phase shift of 180 degrees.

Figure 14 shows a case when the reference signal is 120 degree and the input sensing signal is 180 degree then the value keep changes in the output signal.

V. CONCLUSION

In this research work, in continuation of previous work, the sensor has been designed to achieve the optimized sensitivity using ANSYS tool and for similar values, the sensor has been fabricated. After the sensor fabrication, we focused on the MATLAB code for finding the location of target and distance with the help of the change in phases that occurs due to the deformation of the signal. From the change of phases and the amplitude of the signal obtained we can analyze the signal to predict the location of the target using the sound waves.

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