Design of Stretching Unit for Continuous Β-Phase PVDF Film and Analysis of Piezoelectric Film Sensor for Transducer Applications

Mr. Vishwanath Patil*, Dr. Anjana Jain

Lecturer, Department of Mechanical Engineering BTL Institute Of Technology & Management Bangalore / Scientist , National Aerospace Laboratories Bangalore

Abstract-

Piezoelectric polymer, poly (vinylidene fluoride), PVDF is a widely used fluorocarbon polymer with varied range of applications. PVDF is known to exhibits scientifically interesting and technologically important electrical properties due to their polar structure. When it is subjected to mechanical deformation, it becomes electrically polarized and exhibits strong piezoelectric and pyroelectric properties i.e. the material can be used as a plastic transducer element, which will generate electrical charge as a result of externally, imposed mechanical or thermal fields. PVDF polymer exists in four different forms namely alpha, beta, gama and delta. Beta (β) phase is the well-known piezoelectric form of PVDF. Beta-phase PVDF is produced from film stretching or rolling the films at certain temperatures. To obtain the β phase of film stretching equipment required. So film can be stretched stage by stage. The condition required for stretching the PVDF film can be obtained by passing the film through three heated rollers. The concept is similar to that of a sugar cane squeezing machine. Here we are including heaters to heat the rollers from the inside. The stretching unit consists of three rollers of diameter 40mm. Center roller is fixed permanently to the frame, but can rotate freely in the position, and the other rollers is made to slide up and down above the fixed roller to achieve a good compression of the film and a stretch ratio of 4:1. The sliding roller is fixed to two slides at each end, which slides on the walls of the frame. The slides are moved up and down with the help of two screws which is operated manually and the required pressure is also obtained to have a stretch ratio of 4:1.Characterization of film before and after stretching by using methods X-Ray Diffractometer, Raman Scattering equipment, Differential Scanning Calorimeter, Scanning Electron Microscope and Infrared spectrum. Sensor was analyzed using software Ansys, the results obtained were correlated with the experimental results. Test case available in literature was also considered and the results were validated. The work can be extended to complex structures.

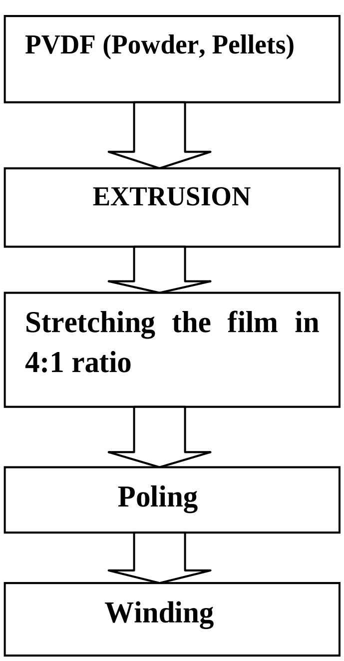
Key words: *Piezoelectric polymer, PVDF polymer, Beta (β) phase, stretching unit.*

I.Introduction

Poly (vinyldene fluoride) has been synthesized in the 1940s yet its ferroelectric property was discovered in late 1960s. PVDF copolymers have been materials of interest since 1990s with the ignition of artificial muscle industry. PVDF is generally used in structural health monitoring systems as pressure and volume displacement sensors due to its exceptional chemical stability and mechanical flexibility which can be easily conformed to complex surfaces. Moreover, its biocompatibility makes PVDF sensor a desirable candidate to be used in biological environments. Besides its sensing capability, PVDF is also applied in the actuation mechanisms that can be thermally optically or electrically stimulated.

A polymeric material poly (vinyldene fluoride) (PVDF) is known to have polar characteristics and piezoelectric properties. Hence, PVDF films have been widely considered in sensor and actuator applications. Different processing techniques for PVDF films such as spin coating and solution casting were introduced by Benz et al. and it was shown that production method of PVDF films is vital in terms of its piezoelectric activity. Therefore, optimization of process conditions and characterization of the end products are crucial to screen and enhance the desired properties of the films.

II.Methodology



Optimization of PVDF film production technique is crucial in terms of the electro active characteristics of the films. Solution casting and electro spinning were chosen for processing the PVDF films. Design of Experiments approach was utilized to monitor and to achieve desired electro active and geometric properties such as polar crystalline formation, film morphology and uniformity. Individual effects and interaction of process parameters were observed to determine the optimum process conditions.Crystallinity and polar crystal phase formation in PVDF films are critical when electro activity is investigated. Following the PVDF film production, further mechanical treatment, especially stretching, are applied to the films to increase the β-phase crystallite portion.The polar β-phase in stretched and un-stretched PVDF films was explored to predict the potential electro active behavior of the films.

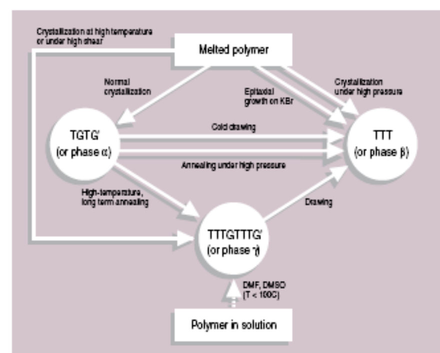


Fig.1 Block diagram indicating different phases of PVDF

III. Basic concept of stretching unit

In this concept film is stretch stage by stage using compound gear arrangement. The stretching unit consists of three rollers of diameter 40mm.Center rollers is fixed permanently to the frame, but can rotate freely in the position, and the other rollers is made to slide up and down above the fixed roller to achieve a good compression of the film and a stretch ratio of 4:1. The sliding roller is fixed to two slides at each end, which slides on the walls of the frame. The slides are moved up and down with the help of four spring screws, which is operated manually and the required pressure is also obtained to have a stretch ratio of 4:1.Rollers are heated by using thermocouple rods and between each unit kept the heaters for heating the film and center rollers are rotated or moved by using gears.

ISSN: 2278-0181
Vol. 2 Issue 12, December - 2013

IV. Actuation and Sensing

The use of piezoelectric materials for actuation and sensing has been demonstrated extensively over the years. There are different piezoelectric modes of actuation available. The duality between actuation and sensing is stressed. The piezoelectric strip is used as sensor by measuring the electric charge appearing on the electrodes. The electrodes are short-circulated so that a zero electric field is enforced (E=0)

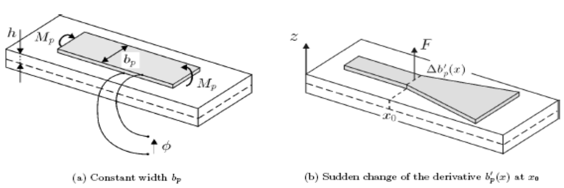
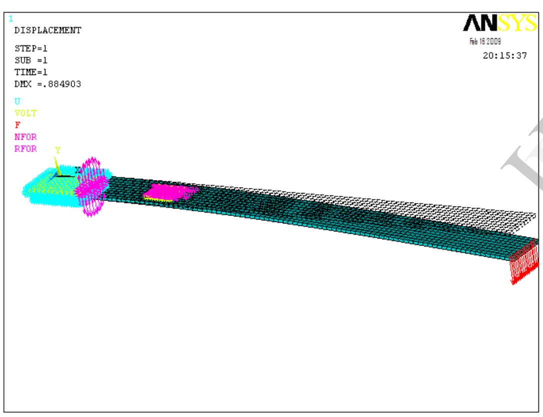
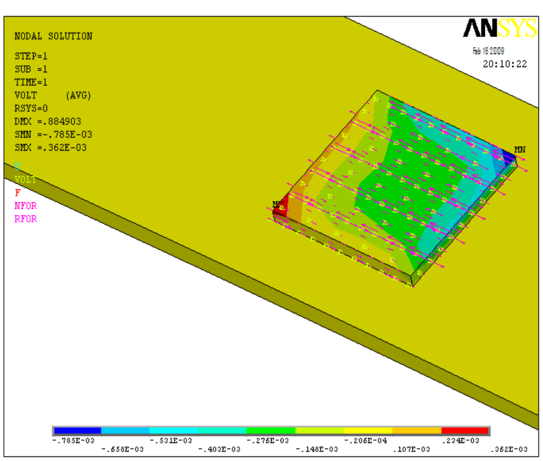


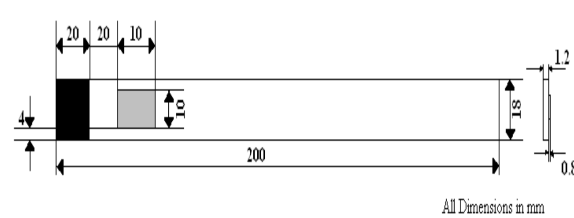
Fig 2. Piezoelectric film actuator





V. Finite Element Modling

A cantilever beam was considered and the piezo-sensor developed was securely glued on to the structure near the clamped end. Care was taken that the glue was thinly applied to the sensor as well as to the structure in order to mount it. This was done to avoid the stiffening effect of the thick glue, which does not induce any strain in the sensor when it becomes hard after curing. A minimum of one day is required when araldite is used as glue, and a minimum of two days is required for curing when shear gel is used for the purpose. In the building of the structure, silicon gel was used, since the sensor can be removed after experiments with ease. Use of araldite causes permanent bonding of the sensor to the surface of the beam. Next a load of 50g plus pan weight was applied on the free end of the cantilever beam. The voltage output was observed in a voltmeter included in the experimental setup. The dimension of the cantilever and placement of the sensor is described in the figure. And FE result is matched with Experimental result. The structure considered in experiment was modeled and meshed in Hypermesh and the experimental results were correlated with the analysis. The results obtained are tabulated in table.



Experimental result (mV)	FE result (mV)
0.284	0.331

Table 1

VI.Conclusion

To convert the phase of the film from α phase to β phase, a stretching unit was designed and fabricated. Working of the unit is simple and can be used independently. Film from the extruder could be continuously stretched and meters of β phase PVDF can be obtained. Automation for the entire process was made so that manual work can be eliminated. The film after being stretched were subjected to various test for characterization like X-ray diffraction, Infrared spectroscopy etc. Films were also subjected to tensile test in Instron machine and its mechanical properties were noted.The sensor thus fabricated was subjected to experimentations to note the behaviour of the sensor. Sensor was also tested in the acoustic mode to widen its applicability. The test reveals that the properties of the sensor have to be improved when compared to commercially available sensors.Sensor was analyzed using software hyper mesh 8 and ANSYS and the results obtained were correlated with the experimental results. Test case available in literature was also considered and the results were validated. The work can be extended to complex structures.

VII.References

1. Cady, W.G. Piezoelectricity. New York: *McGraw-Hill Companies*,

2. Fukada, E. *"History and Recent Progress in Piezoelectric Polymers Research"*. !998

IEEE Ultrasonics Symposium (1998) 597-605.

3. Agarwal, B. D. & Broutman, L. J., 1990, Analysis and Performance of Fiber Composites, John Wiley, 2nd edn.

4. Eer Nisse, E. P., 1967, 'Variational method for electroelastic vibration analysis', IEEE Transactions on Sonics and Ultrasonics, 14(4):153–160.

5. Haertling, G.H. *"Ferroelectric Ceramics: History and Technology." Journal of the*

American Ceramic Society 82.4 (1999) 797-818

6. Barsoum, M. Fundamentals of Ceramics. New York: *McGraw-Hill Companies*, 1997

7. Seymour, R.B., and G.B. Kauffman. *"Piezoelectric Polymers."* Products of Chemistry

67.9 (1990) 763-765.

8. Furukawa T, Ishida K and Fukuda E 1979 *J. Appl. Phys*. 50, 4094

9. E. Venkatragavaraj, B. Satish, P.R. Vinod and M . S Vijaya. J.Phys, D;*Appl*, *Phys*. 34