



The Fabrication of Local Piezoelectric Sensors Using Hydraulic Pressing System Based on PLC

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Abstract

In this study, the local PZT-PVDF composite sensors are produced. The PLC based hydraulic pressure system (250kgF) is as specially designed and fabricated to produce these sensors. The composite sensors are threated under pooling condition in silicon oil at 30 minutes, 120°C. Frequency-voltage characteristics of the piezoelectric sensor that integrated on vibration measurement system are defined, in addition d_{33} (piezoelectric coefficient), capacitance (C), and Q_m (mechanical quality factor) values are determined. It is seen that, fabricated these sensors have 2.5 to 3.7 V_{pp} (pick to pick) voltage at 10Hz resonance frequency. d_{33} and Q_m values of the mentioned sensors are characterized as 10.5-8.6 , 3.7-2.5, respectively. In lower frequency, these sensors which have maximum 3.7 V_{pp} voltage may use as strain sensor, vibration sensor, atomic force microscope cantilever piezoelectric sensor, etc. For the first time, the local piezoelectric sensors are fabricated, and PLC based hydraulic pressure system is designed to produce them in Turkey.

Keywords: Fabrication, Hydraulic Pressure, PLC, Piezoelectric Sensor.

1 Introduction

Smart materials that has piezoelectric properties, find a diverse range of applications in the technology, industry and other research department [1, 2]. Lead zirconatetitanate (PZT) families are the most used in this area, because of they have high piezoelectric properties such as; piezoelectric coefficient d_{ij} , piezosensitivity $d_{ij}/\epsilon\epsilon_0$, Young modulus (Y), mechanical quality coefficient Q_m , electromechanical boundary coefficient K_{ij} and small loss tangents etc. [3,4].

There are many works about PZT and its applications, in addition, some scientist studied composite PZT material using Polyvinylidene fluoride (PVDF) polymer materials and investigated their electromechanical properties [5-10]. PZT and PVDF composite materials show different electromechanical feautres when it's evaluated together as compared to individual [11, 12].

Energy harvesting can be defined as converting ambient energies such as vibration, light, radio frequency energy, temperature etc. to available electric energy by using energy conversation materials like piezo based materials. The electric energy which is obtained from energy conversation materials are stroged on energy harvesting capasitors

for power electric devices [13, 14].

Piezoelectric energy harvesting devices are captivating interest to decrease the power consumption and use of batteries which are consired cost, harmful to the environment, and limited life. Although a number of piezoelectric materials exist, the piezo based PZT and PVDF composites has become one of the most common materials for design of piezoelectric harvester devices. The combination of some excelent properties of the PZT and PVDF composites such as high flexibility, high toughness, high piezoelectric coefficient etc. make it a perfect choice for many applications including vibration sensor, dynamic strain gauges [15]. Current approaches on fabricating piezoelectric sensor are mainly based on a machining approach. The main steps of conventional fabricating system are based upon a hydraulic press. A hydraulic system can either be pumping controlled or valve controlled. Valve controlled systems use electro-hydraulic valves which are used to control the flow of fluid in the system [16-19].

In this study, firstly an industrial solution of the hydraulic pres control which has 250 kgF is realized by using a programmable logic controllers (PLC), secondly, it is obtained local PZT-PVDF sensors via hydraulic pressure

system by controlling with PLC. In addition, the piezoelectric properties of the sensors are determined.

2 Material Method

2.1 Hydraulic Pressure System

The hydraulic pressure system covers some parts of industrial component such as; PLC (Programmable logic controller) control unit included HMI (Human Machine Interface), electrical motor, proportional and directional valve, oil tank, pressure transducer (0-10 volt), pressure gauge etc, as shown in Figure 1.

PLC Control Unit of the hydraulic press is realized by using a programmable logic controller Simatic S7-1200, manufactured by Siemens. The controller program of S7-1200 and configuring of the HMI panel are built using SIMATIC STEP 7 Basic 10.5 software.

The hydraulic pressure system works with button groups

such as start, stop, emergency stop, and also it can be controlled as manually. The operator enters set up values of some parameter such as pressure, temperature, working time etc. by way of the HMI.

According to these parameter values, the system starts automatically working using by software commands into PLC. Placed powder mixtures (PZT + PVDF) into suitable a mold between upper and down jaws have been treated under working conditionals like pressure, temperature, working time. At the end of system's working time, the piezoelectric composite into mold is occurred as solid state. In the next process, lower and upper layers of obtained composite based piezoelectric sensors are attached the electrodes. Another process called poling is made by through High Voltage Amplifier (Gwinstek GPD-3303S – Figure 2).

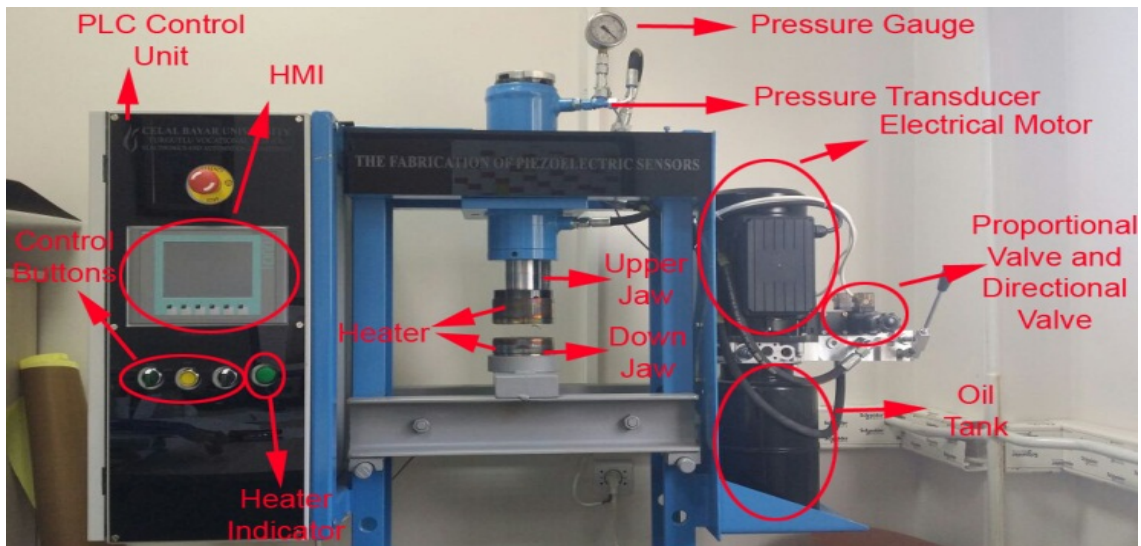


Figure 1. PLC based hydraulic pressure system.

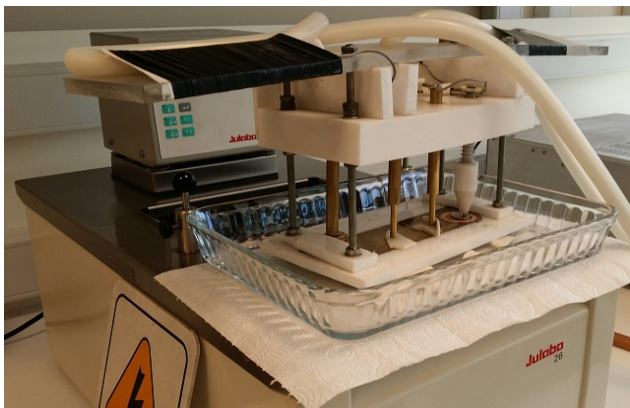


Figure 2. High voltage amplifier for poling process (Gwinstek GPD-3303S).

The mentioned hydraulic system based on PLC actually has been realized in the Researcher and Development Laboratory at Electronics and Automation Department of Celal Bayar University, Turgutlu Vocational School. This system will be used for research purposes in the field of hydraulic systems control, as well as for training automation students.

2.2 Preparing the Sensors

The commercial PZT materials are used to obtain the composite sensors. Different type of PZT (PZT5A, PZT5H and PZT8 – APC Piezoelectric) 50% weight and PVDF (Alfa Aesar) 50% weight are used. PZT and PVDF materials are weighed in scales and then mixed in agate mortar carefully. Two kind of mold are made to preparing disc shape composite sensor. One of them is 32mm and the

other is 25mm diameters. The mixed materials are placed into mold and then pressed with hydraulic pressure system in 160°C at 30 minutes. Six different PZT-PVDF composite materials are obtained as shown in Table 1. The brass

electrode is pasted on the surface of the sensor for pooling. The sensors are polarized at 1050 Volt electric field and 120°C in silicone oil. Fabricated sensors and their physical features are shown in Fig.3, Table 1, respectively.

Table 1. Physical features of PZT sensors.

Name	PZT (50%)	Polymer (50%)	Diameter (mm)	Thickness – d (µm)	Surface Area-A (mm ²)	d/A (10 ⁻⁴ mm ⁻¹)
PZT5A_1	PZT 5A	PVDF	32	321	803,84	3,99
PZT5A_2	PZT 5A	PVDF	25	402	490,63	8,19
PZT5H_1	PZT 5H	PVDF	32	318	803,84	3,95
PZT5H_2	PZT 5H	PVDF	25	399	490,63	8,13
PZT8_1	PZT 8	PVDF	32	322	803,84	4,01
PZT8_2	PZT 8	PVDF	25	402	490,63	8,19

Table 2. Piezoelectric properties of sensors.

Name	d ₃₃	Capacitance- C (pikoFarad)	Q _m	V _{pp} (Voltage)	Frequency (Hz)
PZT5A_1	10.5	308	3.5	2.8	10
PZT5A_2	10.5	301	3.5	3.7	10
PZT5H_1	10	296	3.3	2.5	10
PZT5H_2	10	295	3.3	3.7	10
PZT8_1	8.6	288	3.1	2.9	9.5
PZT8_2	8.6	285	3.1	3.4	9.5

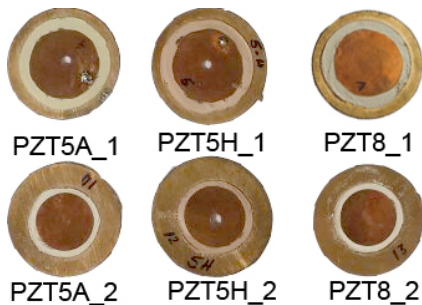


Figure 3. Fabricated sensors.

2.3 Vibration Measurement System

The electrical performances of the piezoelectric sensors are analyzed by vibration measurement system (Fig.4). Voltages out put of the piezoelectric sensor are compared with each other according to vibration frequencies. LDS (Ling dynamic system) shaker is used to define vibration conditions. Vibration frequencies and amplitude are determined by WF1944 function signal generator, PA500L power amplifier is used to generate strong signal pro-

cessing. AC (Alternative Current) output voltages measurements both piezoelectric sensor and load cell during vibration are measured as no load with Agilent DSO-X 3014A digital stroge oscilloscope. Pre-stress value of the piezoelectric sensor is performed with Miniature Delta-Tron TEDS Accelerometer Type 4508B load cell. In addition, the d₃₃, capacitance, Q_m values of the sensors are calculated using system.

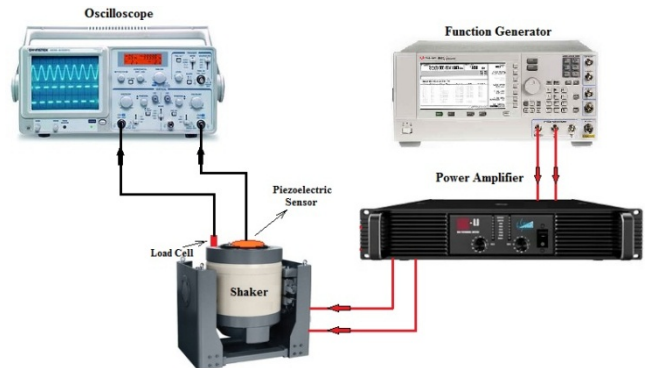


Figure 4. Vibration measurement system.

3 Results and Discussion

The frequency vs voltage (pick to pick) behaviours of produced sensors are shown in Figure 5-9. It is seen that from Figure 5, 32mm diameters sensors have different voltage pick each other in 10Hz frequency. PZT5H, PZT5A and PZT8 sensors indicate about 2.5, 2.8 and 2.9 V_{pp} respectively. Different situation is occurred for 25mm diameters sensors in Fig.6. PZT5A and PZT5H sensors have almost same voltage (about 3.9 V_{pp}), and PZT8 sensor has 3.5 V_{pp} in Fig.6. Therefore, the voltage pick values of 25mm diameters sensors bigger than ones of the 32mm diameters sensors.

The d/A rate of the sensors are different for 32mm and 25mm diameters sensors. It can be come from different quality factor of the sensors. The Q_m factors are calculated using FWHM of frequency-voltage graph of the sensors, and d/A rates. In addition, the sensors have different thickness and surface areas (in Table 1) as well as sensors have different piezoelectric properties (Table 2).

When it is considering the PZT5As, PZT5Hs and PZT8s which have different diameters between each other in Figure 7, Figure 8, and Figure 9, it seems that the PZT+PVDF composites with 25mm diameter have higher voltage values than that others for all PZT various. It can be concluded that the differences are come from surface area and the thickness of the sensors. In addition, piezoelectric coefficient (d_{33}) values of the sensors are very close to each other as well as mechanical quality factors. It is seen that these sensors have similar piezoelectric properties, and this may be the 50% PVDF used in composite. It is planned that the piezoelectric sensors will be produced by increasing rate of PZT in subsequent studies, and the energy capability of these sensors will be realized on energy harvesting system.

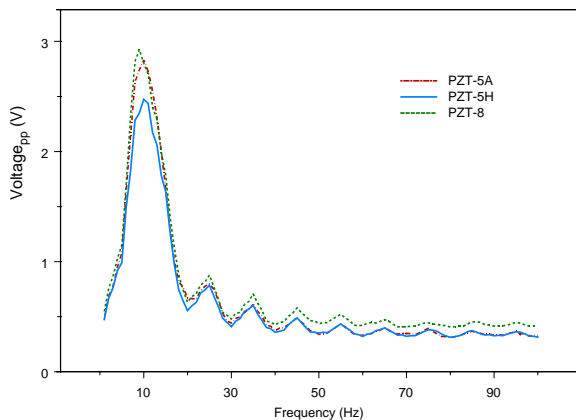


Figure 5. Frequency – Voltage graph of PZT sensors with 32mm diameter.

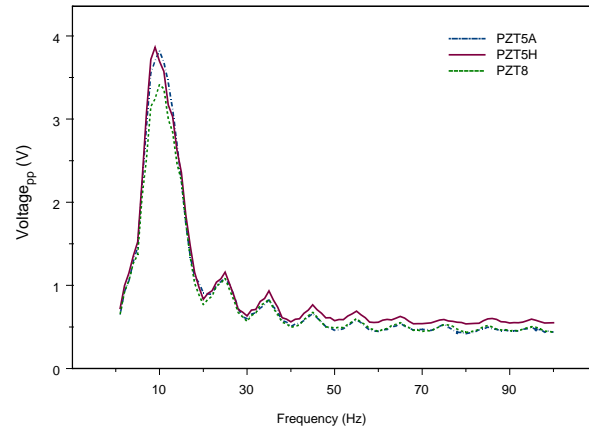


Figure 6. Frequency – Voltage graph of PZT sensors with 25mm diameter.

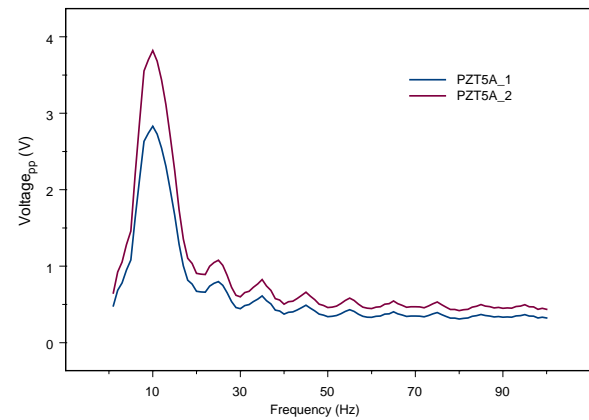


Figure 7. Frequency – Voltage graph of 32mm (PZT5A_1) and 25mm (PZT5A_2) diameters PZT sensors.

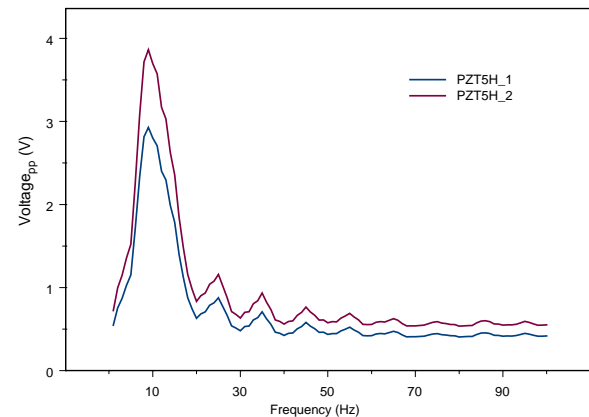


Figure 8. Frequency – Voltage graph of 32mm (PZT5H_1) and 25mm (PZT5H_2) diameters PZT sensors.

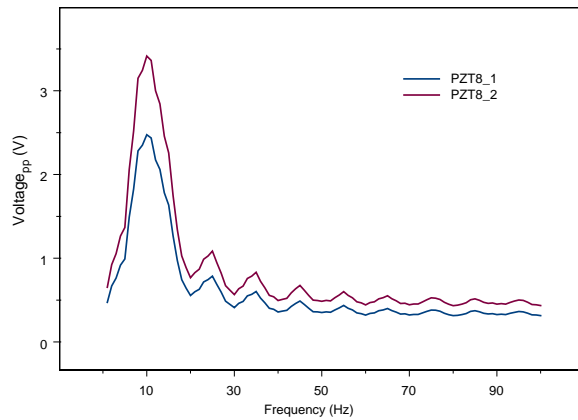


Figure 9. Frequency – Voltage graph of 32mm (PZT8_1) and 25mm (PZT8_2) diameters PZT sensors.

4 Conclusion

In this study, the local PZT composite sensors are produced by PLC controlled hydraulic pressure system, and unique pressure system is designed. It can produce sensors of various dimension using by pressure system, in addition, by making transformations in the pressure system, the series of production can be performed.

Acknowledgements

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