DOI 10.5162/SMSI2023/P42

PVDF SENSOR ARRAY FOR UNSTEADY WALL-PRESSURE MEASURMENTS IN SHOCKWAVE-BOUNDARY LAYER INTERACTIONS APPLICATION

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Summary:

This paper presents the development and 3D integration of a PVDF piezo-film sensor array for unsteady wall-pressure measurements in a turbulent SBLI (Shockwave-boundary layer interactions). The sensor array is developed and tested inside the supersonic wind tunnel in an SBLI configuration. The sensor array is large and have no obstacles on the surface. The sensor system has been 3D integrated and no bond wires are needed. With this type of large area sensor array several local pointwise measurements can be taken without disturbing the flow field. The dynamic wall-pressure field of a turbulent SBLI at Mach 2 is measured and displayed. The obtained results show good agreement with other studies present in literature. The PVDF setup is compared with the standard state-of-the-art sensor used for unsteady pressure measurements, a reference piezoresistive transducer, highlighting the good qualities of the proposed sensor.

Keywords: PVDF Sensors, Sensorarray for unsteady wall-pressure measurements, 3D sensor integration

Background / Motivation

One of the most challenges in development of next engine generation (Geared Turbofan Engine – GTF Engine) is to provide a separation-free and stable flow over the whole range, especially at the edges. The next engine generation should achieve a fuel burn reduction of 11%. It's the goal in the EU climate-neutral aviation Clean Sky 2 program [1] to reduce the CO2 and noise emission in the year 2030 approximately 30%. To optimize the aircraft structure to reduce internal and external noise generated by TBL pressure fluctuations, high fidelity characterization of the wall pressure spectrum in spatial wavenumber space and in temporal frequency is needed. Existing sensor solutions in practice do not meet all the requirements. Up to now, bulky and expensive semiconductor-based pressure sensors such as silicon-based piezoresistive sensor solutions from company Kulite have been used [2]. They do not provide enough information about the interactions, and show limitations in resolution and frequence domain. To overcome the above mentioned limitations we have developed a new high performance wall mounted sensor array for surface unsteady pressure and wall shear stress measurements for future aircrafts.

Description of the New Method or System

In this paper we present a 3D piezoelectric sensor array setup for use in SBLI (the concept in shown in figure 1).

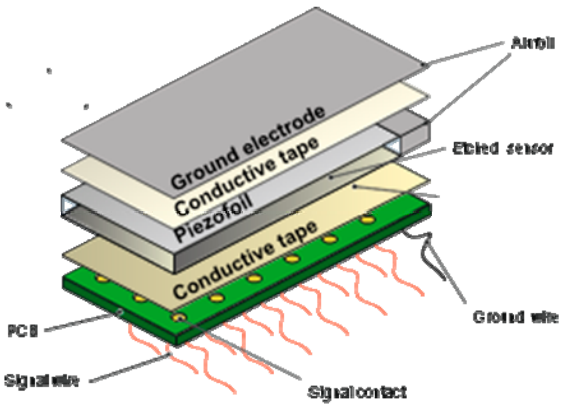

Fig. 1. Concept of the PVDF-based sensor array. The structured piezofoil has been embedded between two conductive tapes as electrical contact but also as shielding. In our system no bumps or wires are needed. The sensor surface is obstacle-free and so does not interfere with the flow.

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We will focus on the sensor structuring technology, the electronics, the packaging and shielding concept in details. The sensor system does not need any bumps or bond wires for contacting, so it can be realized very small in size and compact. The electrical path is vertical and so can be very short. The sensor array has been realized using PVDF-foils [3]. This material has been used in a wide range of applications [4]. The foils are flexible and can be very thin (110µm in this project). The foils are based on the polymer polyvinylidenefluoride (PVDF). Metal layers (Ag, Al, Au) are deposited on both sides of the foil for electrical contacts. The metal layers (in this paper Ag-based) have been structured using different methods (laser etching, wet etching, milling) to form small electrodes for the piezoelectric sensors. The sensor setup can be seen in the figure below (figure 2).

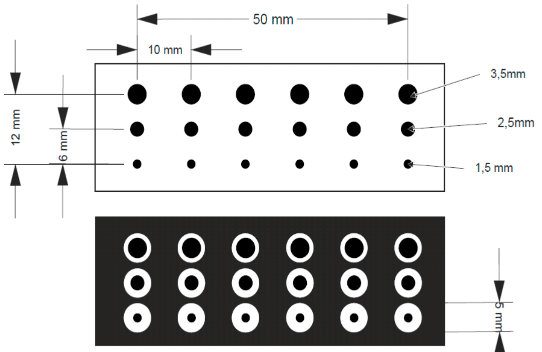

Fig. 2: Sensor array with 18 sensors. Different sensors layouts have been realized by using laser ablation, wet etching and mechanical milling. Laser ablation and milling provide the best sensor performance, whereas the wet etching is not really suitable due to the low selectivity. Black areas are the Ag-electrodes remaining.

The sensor array can be integrated on different surfaces, such as air foil.

Results

The sensor array with 18 and 48 sensors, electronics for signal acquisition and 3D packaging technology have been developed. The sensor system is flexible and can be integrated in all surfaces in aerospace. Tests in the supersonic wind tunnel (figure 3) with the developed sensor arrays and reference sensor system from Kulite have been conducted.

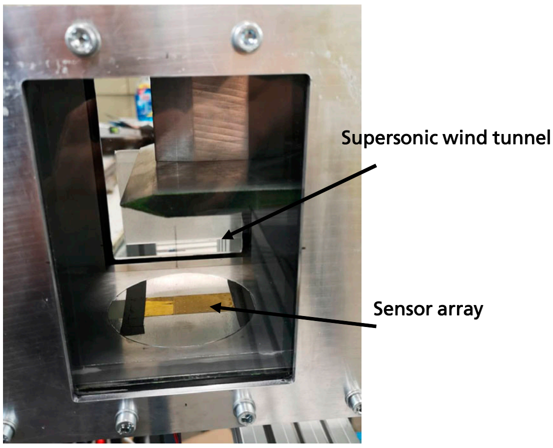

Fig. 3: View of the window in the supersonic wind tunnel and the sensor array.

It can be demonstrated (figure 4) that the new sensor system is able to match the reference sensor signal precisely.

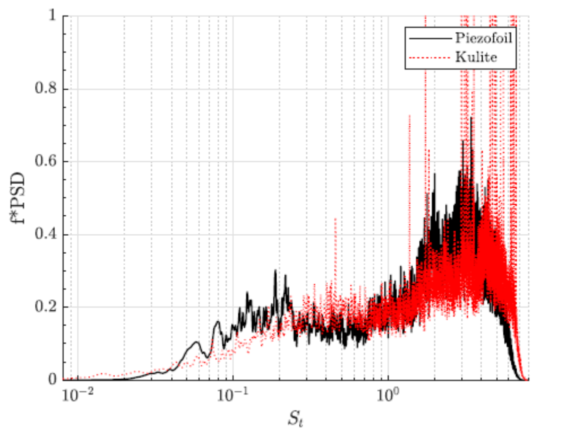

*Fig. 4: Comparison between piezofoil sensor (position 1) and reference sensor using f*PSD. Red – reference sensor, and back the piezosensor.*

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