Harvesting energy to power sensors that monitor air pollution

The REM Project

The original Italian title of this project was "Recupero di Energia Meccanica da fluidi per internet delle cose e sensori remoti" from which its acronym – REM – was derived.

Final scope of the project

Recovery of Mechanical Energy from fluids to feed an Internet of Things (IoT) node that monitors diesel-engine exhaust gases.

Partners

- EnginSoft (project coordinators) https://www.enginsoft.com/
- The Center for Biomolecular Nanotechnologies of the Istituto Italiano di Tecnologia (IIT) https://www.iit.it/centers/cbn-unile
- Web Elettronica https://www.webelettronica.com/index.html

Fig. 1 – Partners' logos

The global challenge of air pollution

Poor air quality is a growing threat to public health, and air pollution contributes to more than seven million deaths annually worldwide. Governments are seeking low-cost and user-friendly solutions to monitor air quality.

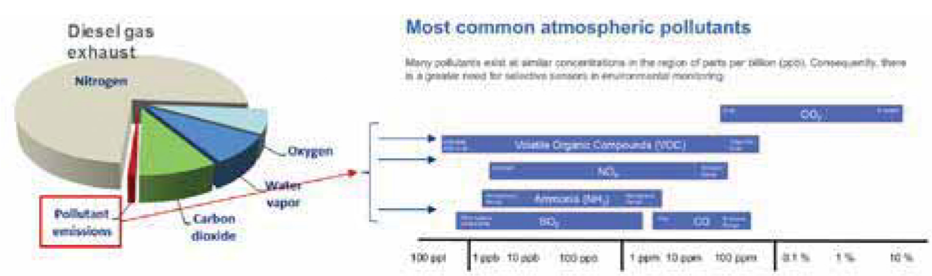

Fig. 2 – The most common atmospheric pollutants

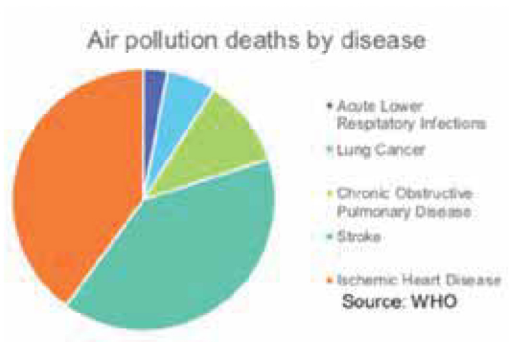

Fig. 3 – Air pollution deaths by disease

The Internet of Things (IoT): the vision of a "Smart Environment" around us

The vision of a "Smart Environment" is one of a physical world that is richly and invisibly laced with sensors, actuators, displays, and computational elements, embedded seamlessly into everyday objects and connected through a continuous network (Mark Weiser, Ubiquitous Computing).

An IoT node will be able to sense, visualize, analyze, and communicate about the environmental air pollution around us at any time.

Fig. 4 – J. Gubbi et al. / Future Generation Computer Systems 29 (2013) 1645–1660

Convergence in new technologies for energy harvesting

Smart IoT nodes require energy to function. It is important to develop miniature devices with the ability to sense, visualize, compute and communicate while requiring very low energy. This requires the study of Micro-Electro-Mechanical Systems (MEMSs), Digital Signal Processing (DSP) in digital electronics, and wireless communications (Wi-Fi).

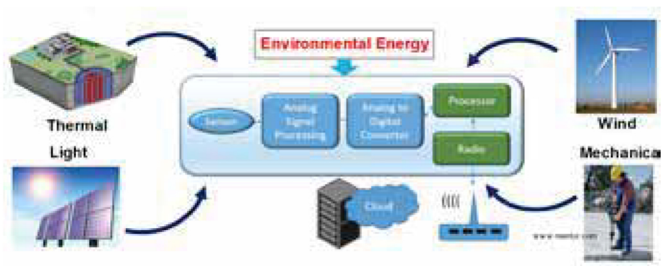

Fig. 5 – Environmental energy harvesting

Fig. 6 – Environmental energy transfer

Energy harvesters convert energy from environmental sources (light, thermal, wind, vibrations, etc.) into electrical energy to power autonomous microsystems and to extend battery life in small electronics.

The energy harvesters in MEMS are used as power sources in wireless sensor networks (WSN) which are used for structural health monitoring, building climate control and automotive sensing.

Flexible Aluminum Nitride-based piezoelectric transducers

The project is studying a piezoelectric flag transducer and is considering two technologies:

- Aluminum Nitride (AlN) thin film
  - o Good piezoelectric coefficients (4-5 pm/V)
  - o High temperature performance (up to 1150 °C)
  - o Biocompatibility
  - o Growth on different flexible substrates (polyimide, kapton tape, PEN)
- Flexible Kapton substrates (polyimide)
  - o Stable at a large range of temperatures [-273 to +400°C]
  - o Compatible with all the main microfabrication building blocks for MEMS.

This flexible system efficiently transforms strains of flexible substrate from fluids or vibration into piezoelectric energy. The first prototypes have been successfully created and the flag is sensitive even to very low-speed air flows, such as a breath. Directly connected to an oscilloscope, the 2.5cm-long flag generated a few hundred millivolts.

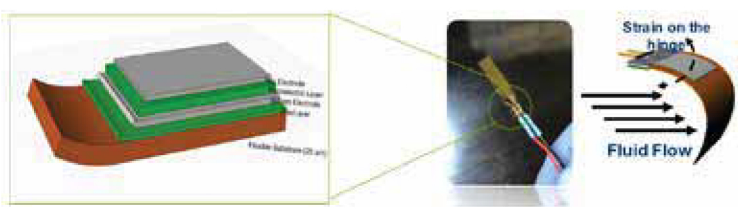

Fig. 7 – Transducer layout

	Polyimide «Structural Flag»	AlN «Piezoelectric layer»	Parylene «Water insulator»
Length (cm)	1 - 3	0.5 - 1	1 - 3
Width (cm)	0.4 - 1.2	0.2 - 1	0.4 - 1.2
Width (µm)	25	1	2
Density (kg/m³)	1420	3300	1289
Young's Modulus (GPa)	2e9	348	2.75
Poisson Coefficient	0.34	0.3	0.4

Fig. 8 – First tests and material properties

Fluid Structure Interaction (FSI) analysis

There are ongoing, detailed FSI analyses to numerically characterize the flag's oscillation.

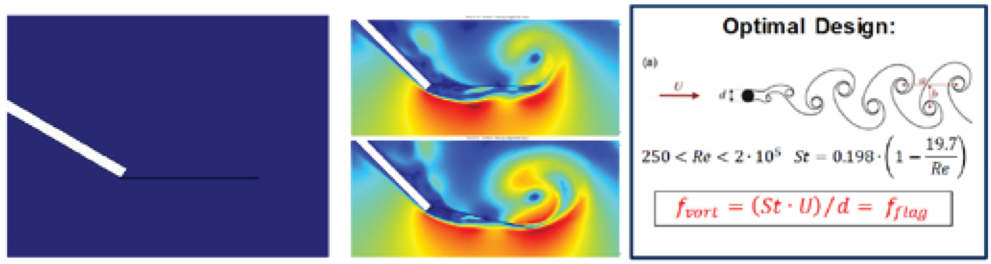

Fig. 9 – First FSI considerations (From: Petroni S., Rizzi F. et al. RSC Advances vol. 5, issue 18, pp. 14047-14052 (2015))

The optimal system design has to be found in terms of bluff body and flag geometries, the flag's orientation with respect to the flow, and source generation. To maximize the FSI interaction, the preliminary strategy will be to design the bluff body's geometry, the flag material and the geometric characteristics to select those flag resonance modes that are as close as possible to the Von Karman vortex frequencies generated by the bluff body.

Digital twin and sensor dashboard

The final physical system, consisting of a transducer and an electronic circuit for the harvesting, will be a low-cost device, accessible to and usable in any context, from private companies to industries and public organizations. The REM project's final goal is to provide a service based on a digital twin of the whole system with a dashboard accessible from both PC and mobile devices that allows the end user to check data from the sensors in real time.

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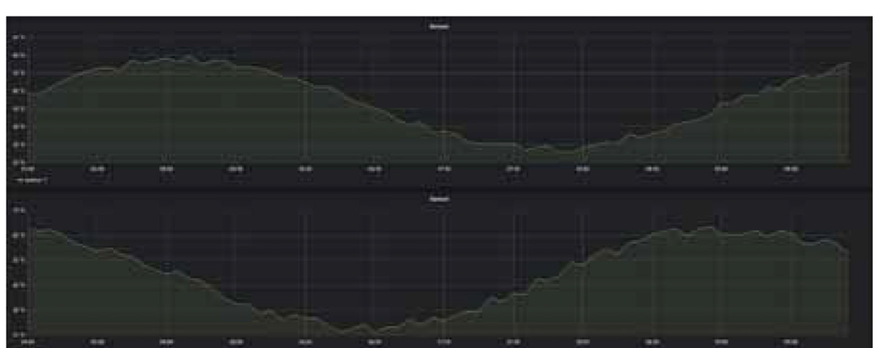

Figure 10 – Dashboard for sensor monitoring