Vibration energy scavenging powered wireless tire pressure monitoring sensor

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Abstract

Tire pressure monitoring (TPM) is extremely important for passenger safety. Taking into consideration the recent USA and EU acts, which impose TPM in all new vehicles, a total of 10 batteries are to be disposed into the environment in a car lifetime. In this work an original solution of a Wireless Tire Pressure Monitoring Sensor (WTPMS), powered by a piezoelectric bimorph scavenger is presented.

1 Introduction

Scavenging of low level ambient vibration energy via piezoelectric bimorphs is characterised by design simplicity, miniaturization and integration potential and high power densities [1]. In a previous work, a coupled modal electromechanical analysis of piezoelectric vibration scavengers was performed and validated experimentally [2]. This study is supported by a finite element analysis presented in a separate paper.

On the other hand, tire pressure monitoring (TPM) is an important factor in passenger safety [3]. Regulated tire pressure could save lives (9% of traffic accidents are caused by improper inflation) and drastically improves tire lifetime (0.2 bar of under inflation increases fuel consumption by 2% and reduces tire life by 25%). Due to recent legislation, wireless battery-powered TPM systems are already being installed. Since the batteries are hermetically sealed, in a single car lifetime an average of 10 batteries and devices are to be disposed of. This problem requires a sustainable solution which could power the sensors for the duration of a car lifetime. As vibrations are abundant in the surrounding of motor vehicles, vibration energy scavenging becomes a feasible solution.

In this work an original solution of a wireless TPM system powered by a piezoelectric bimorph scavenger is thus presented.

2 Wireless Tire Pressure Monitoring Sensor (WTPMS) concept

Inertial vibration energy scavengers are primarily designed to work at a specific excitation frequency so as to maximize energy conversion. In order to determine the amplitudes and vibration frequencies, a series of experiments were performed to measure these values on a car wheel in different on-road conditions: parking, city, open road & highway. To measure the values on a rotating wheel, a commercial vibration logging device was used. The measurements showed high magnitude amplitudes occurring in an unperiodic manner (Fig. 1), thus not limiting the proposed design to a specific eigenfrequency.

Based on these observations, an original Wireless Tire Pressure Monitoring Sensor (WTPMS) was conceived (Fig. 2).

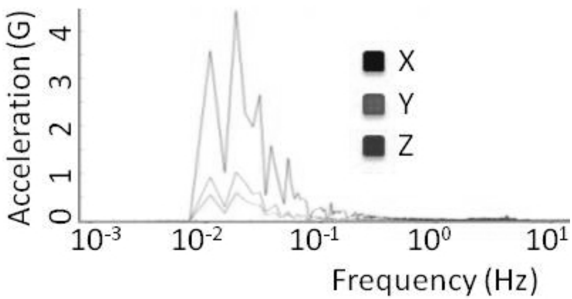


Figure 1: FFT analysis of measurements on a car tire in open road conditions

Figure 2: WTPMS concept: 1) piezoelectric scavenger with conditioning electronics, 2) TPM, 3) standard Schrader valve

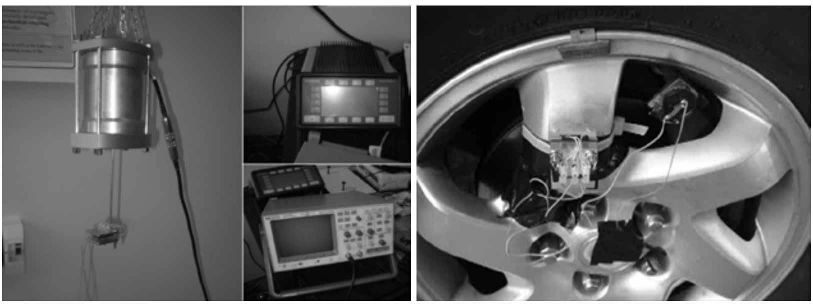
The WTPMS consists of:

- A miniaturised piezoelectric bimorph of suitable design where a parallel connection of the piezoelectric layers is used to obtain better impedance matching with the low resistance of the TPM module.
- An off-the-shelf energy scavenging power supply chip [4] that interfaces to the piezoelectric, conditions and stores the produced energy and drives via a capacitor the pressure sensor.
- A FreeScale MPXY8300 TPM module comprising a capacitive pressure sensor, a microcontroller and an RF transmitter [5]. At specific time intervals, sensor data is accessed, analyzed and placed into the buffer for wireless transmission.

In order to prove the WTPMS concept, laboratory and on-road tests have been performed.

3 Obtained results

Experiments on the WTPMS were carried out on the set-up developed previously for bimorphs' dynamics characterization [2]. Tests were carried out with random vibration signal inputs so as to simulate on- road conditions (Fig. 3a). The control electronics used to manage the energy obtained from the piezoelectric bimorph was optimised so as to assure stable transmission and powering of the TPM in the time necessary to collect and transmit tire pressure data. The data could thus be successfully acquired and transmitted to the receiver proving the WTPMS concept in laboratory conditions.



(a) (b)

Figure 3: Experimental setup (a) and WTPMS system mounted on the car rim (b)

By designing suitable interfaces, the WTPMS was mounted then on a tire rim. The piezoelectric element was mounted perpendicular to the axis of wheel rotation to avoid centrifugal force acting on the scavenger (Fig. 3b). About 6.5 mW were obtained in open road conditions, allowing the WTPMS to be powered while acquiring pressure data and transmitting it to the receiver in the car cockpit.

4 Conclusion and outlook

The functionality of the developed WTPMS system was proven both in laboratory and on-road conditions. About 6.5 mW of power were obtained in short bursts powering successfully the TPM module. Future work on the WTPMS system will include further miniaturisation as well as an optimization of the electrical domain to obtain even higher efficiency. Variations of the presented battery-less concept could be applied to other applications including human or structural health monitoring.

Acknowledgements

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