PRESSURE AND TEMPERATURE MONITORING SYSTEM FOR OFF-HIGHWAY TRUCK TIRES

Alejandro Andrés Alviña Olavarría
Electronic Civil Engineer, working on thesis to get the degree.
Federico Santa María Technical University
Avenida España 1680. Casilla 110-V. Valparaíso, Chile.
Phone: (56-032) 249 88 04 - Mobile: (56-9) 85 01 57 34
Email: alejandro.alvina@alumnos.utfsm.cl
Faculty: Agustín González Valenzuela

ABSTRACT

Tires are essential supplies in mining operations and have great economic impact in the productive process. This work proposes an efficient and economic solution for pressure and temperature monitoring for tires of Off-Highway Trucks. We propose a system to automate this process and to offer a local and remote monitoring service of these variables. The system evaluates the conditions of tires operation in order to react in time and to maximize its lifespan.

The system allows one to monitor the pressure and temperature of each tire, its behavior over time, and to act opportunely when variations that exceed the normal operation parameters happen. In addition, it provides statistical information of tires usage, yield, lifespan, and wears away according to diverse operation conditions in a totally automated way.

INTRODUCTION

In these days we are living a mining “boom” because of the great price of the copper, increasing the country’s income due to this natural resource. But the truth is far from being as glad as we would hope: the “mineral’s law” is decreasing, increasing its hardness, the transport distances, and the depth in the mines, all of those things are pushing for a rise in production costs.

A 2006 study published by COCHILCO [1] said that the tires are among highest level of consumption supplies, with an annual average of US$ 38.1 million. In addition, its consumption would have to increase with the materialization of new projects, in special mineral transport trucks of great tonnage.

This work proposes an efficient and economic solution for pressure and temperature monitoring of tires of Off-Highway Trucks. The idea is to automate this process and to offer a service for in-line and remote monitoring of these variables.

In order to achieve this goal the proposed solution unites hardware and software technologies, such as: a low consumption microprocessor and components; standard and free frequencies of communication; artificial intelligence to detect patterns; and the facility to have the information remotely.

The system allows users to monitor the pressure and temperature of each tire, its behavior over time, to react opportunely when an alert like variations that exceed the normal operation parameters happens, to evaluate conditions of operation to maximize the duration of tires, and to increase the consequent economic and logistic benefits of the productive process of the mining task. In addition, it allows the company to record statistical information of tires usage, yield, lifespan, and wears away according under diverse tasks in a totally automated way.

The pressure and temperature monitoring system consists of transmitting sensors that continuously measure these tire variables. Then each sensor transmits a low power radio signal to conserve its battery, making measurements more often when variations or extreme values are registered and with lower frequency when the temperature and pressure are stable. The information is received by a module on board the truck, allowing handling local alarms before extreme or risk values occur. In addition, the system wirelessly sends all the information to a remote central server, where the information is processed. As a result, users can make logistic and maintenance decisions within the productive process, incorporating the registries in a data base, its statistical analysis and the generation of an *expert system*, the administration and maintenance of this consume can be facilitated.

So far, a test module has been developed for sensing and transmitting information from the tires towards a central receiver on board a truck. As our implementation progresses we will expect to integrate a transmitter in order to store this information in a remote data base, to include a Statistical Analysis System, and to incorporate some artificial intelligence in order to complete an *expert system*.

METHODOLOGY

To get an answer to the problem exposed is necessary to consider the solution as a system, the integration of several functional modules, and then, to develop the solution in phases, each of them including test and improves from the previous phase.

In order to define the monitoring system, in its composition and in its characteristics, three stages are verified: an overview of the system, its modularization, and the subsequent integration of these modules.

For a global view of the system is necessary to consider their interaction with the environment, in this case, its location on the truck and in the tire.

The modularization consists in determining the functional requirements and the best way to fulfill them. Then hardware and software are produced to meet those unitary requirements, to work each request as separately as possible, and to have functional modules independent. Those modules are feasible to be tested without necessarily dealing with the whole system; this achieves a breakthrough in parallel and optimizes the time and resources.

The functional requirements are:

- Measure the pressure in the tire.
- Measure the temperature in the tire.
- Have the measured information in the cab.
- Provide measured information to a central database far from the truck.
- Process the information and analyze the results automatically to accelerate and to optimize the tires management.
- Have statistical studies and comparative analysis of the tires performance under each interest factor like: manufacturer, pressure, temperature, terrain, altitude of the mine, and type of truck.
- Be capable to have training with experts, and then mix this experience with the measurements and others informations into an artificial intelligence system, like neural network and genetic algorithms, to make an *Expert System*.

To meet with these requirements it is necessary to choose the right components and design, and later to develop a solid, stable and functional system. The following pages show the first part of this process.

RESULTS AND DISCUSSION

The Tire Pressure and Temperature Monitoring System for large mining trucks, as its name suggests, is to be placed on a truck or machinery in general that uses some type of tire as Off-The-Road (O.T.R .) tires for mining. The next diagram shows the system installed on a truck.

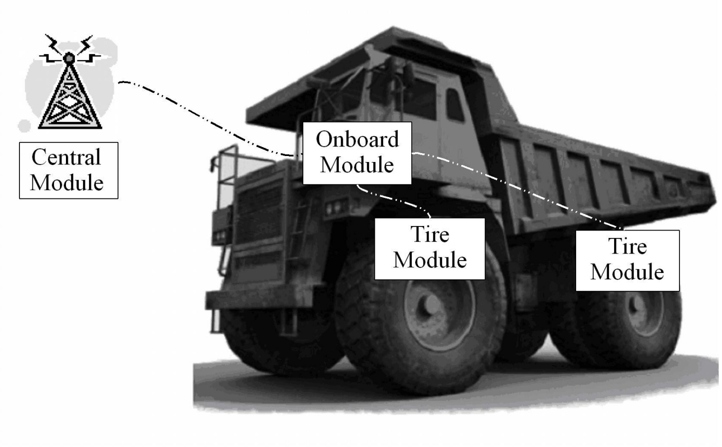

Figure 1: Diagram of the system installed on a truck.

The main design considerations were:

- Efficient management of the power consumed by each component and generally throughout the system, in order to provide low-consumption devices thus prolonging the duration of the batteries, and hence the system itself.
- Accuracy of measurements (sensors), even in hostile environments while trucks are operating.
- We assume that wireless communication protocol (Radio Frequency, also called RF) and associated components can be used globally, according to the norms and standards of international communications.
- The system must be customizable and programmable.

According with the functional requirements and the design considerations, we propose the architecture in Figures 2, 3 and 4.

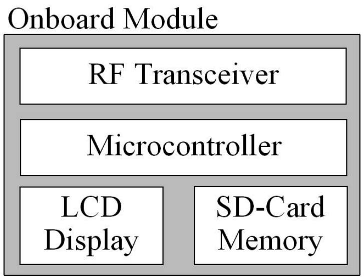

Figure 2: Architecture diagram for *Onboard Module*.

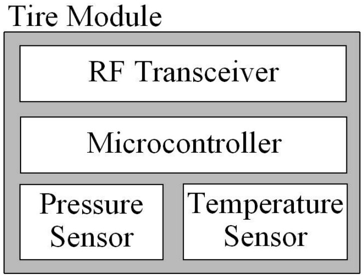

Figure 3: Architecture diagram for *Tire Module*.

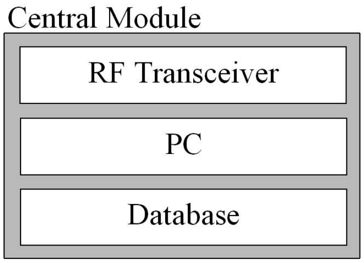

Figure 4: Architecture diagram for *Central Module*.

By researching the great amount of offers on the market, and based in concepts like low-power consumption, size, manufacturer's prestige and economy, next is the description and justification of the choosed components:

- Tire Module Processor:

The processor of this module must be low-power consumption and small, to ensure durability and functionality. We choose from Texas Instrument, the MSP430F2013, among manufacturers like Freescale, Atmel, STMicroelectronics and others. This processor offers:

- Ultra low-power consumption (less than 2 mA in active mode and less than 100 μA in standby mode).
- Five power-saving modes.

- Internal digital clock oscillator.
- Peripherals and other technical characteristics needed in the system.

One of the most important characteristics is its available and cheap development tool called EZ430-F2013, which allows us to program and to develop faster than other tools.

- Onboard Module Processor

We choose the MSP430F1612 from Texas Instrument because the processor on this module must allow the management of different peripherals like local memory, display, and the communication modules. It has enough processing power and a low-power consumption as well allowing independence and durability.

- Temperature Sensor

The market offers a lot of temperature or pressure sensors, but a few of them have both type of sensors integrated in a single chip. We choose the MPXY8021A from Freescale Semiconductor, this is a tire pressure and temperature monitoring sensor compensated and calibrated, fully integrated, with digital output. For this sensor we developed a driver to assure the right interaction with the microcontroller in the *Tire Module*.

- Communications

To accelerate and to optimize the resources of this development we decided to use an off the shelf radio frequency module for communication.
The development of a circuit for communication implies to work with high frequencies, and this takes time because of the circuit design must take into consideration parasite inductances and capacities.
After having chosen manufactured modules, it is necessary to choose the frequency band in which it will work. The Industrial, Scientific and Medical (ISM) radio bands are defined internationally, we decided to use the less crowded 868MHz band to support current and future radio develops. This license-free band is valid in Europe, and there is an equivalent 915MHz band in the USA.
Many manufacturers offer RF modules in this band, but a few of these modules have characteristics such as small size, low power consumption, serial communication with the microcontroller, error detection, link verification and encryption.
These requirements among other are fulfilled by the Aerocomm AC4868 transceiver, for which we developed a driver to interact with the microcontroller.

- Display

In the *Onboard Module* a LCD display is necessary to let the truck driver see what happens in real time and be alert for emergency signals generated by the change in pressure or temperature of the tires beyond the extremes entered into the system earlier, or by a strong variation of some of these variables. For this reason we choose a 4 lines LCD display to periodically show updates in each line the variables of interest of each tire.

- Storage

We decided to use a SD-Card because of its low price, variety of manufacturers, large storage capacity, small size and the relative easy communication with the microcontroller.
The information received by the *Onboard Module* must be stored as a backup and a local database. This type of card has a lot of common with portable and swappable data storage devices, such as floppy disks, Zip disks, miniCD / miniDVD, CD-R/CD-RW, DVD-RW discs and flash storage devices.
But portable storage media like flash memory devices can work under movement, jumping and mild strokes situations, like in the truck.

- Other components

The power comes from battery for all the modules.
The *Central Module* is still under development and we expect to finish it in the next phase of the system construction. Finally, other components are also required, for instance another communication module with farther reaching for links between trucks and the central module, and some software for the computer interface.

The interaction and information flow in each of the modules and between them are displayed in Figure 5.

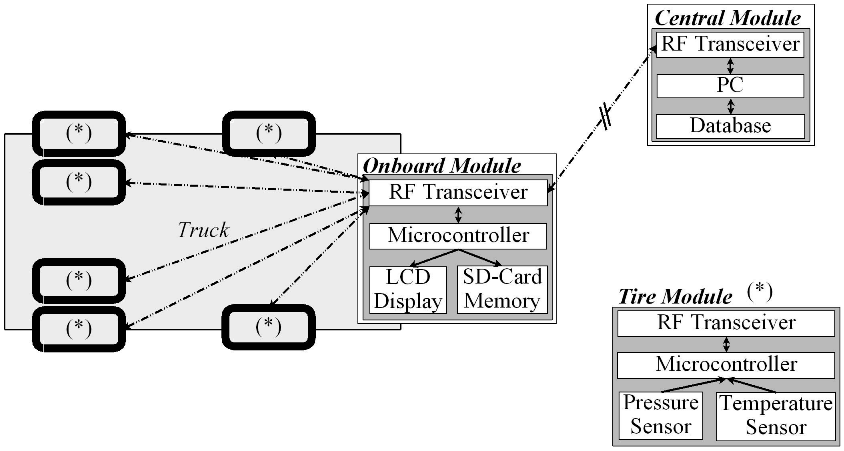

Figure 5: Data flow diagram.

This interaction was tested for each of the functional modules and with the interaction between them. Those tests consist in programs developed to review each characteristic and then to ensure the right operation.

The next development phase involves the implementation of the *Central Module*, the Neural Network and the *expert system*.

CONCLUSIONS

The current method of monitoring tire of the Great Mining trucks is unfavourable for the optimization of resources; it does not allow the timely management of information, which prevents the reduction of costs. Existing solutions are not geared to the scale of the national mining, then, they do not work as an integral system, and then do not satisfied the necessity of manage the information remotely and with easy adaptation to the Great Mining conditions.

The solution proposed allows managing the tires remotely, in real time and with a low level inversion.

The system developed measures pressure and temperature of each tire and then sends this information to an onboard console, where the information is stored, and it can signal early warnings to the operator (driver) if any parameter has been exceeded. The information on the truck is sent wirelessly to a central unit, which analyzed the data, detecting patterns of failure, and ultimately managing remotely the tires.

ACKNOWLEDGMENTS

I would like to acknowledge the support of the Federico Santa María Technical University; it is reflected on my guide professor Mr. Agustin Gonzalez Valenzuela.

I also thank my family and my girlfriend whom have supported, financed and helped me achieve these results.

REFERENCES

COCHILCO, Olivares G. y Valenzuela A., (2006). “Oportunidades de Negocios Para Proveedores de Bienes, Insumos y Servicios Mineros en Chile”, p. 271, 274 [1]

TI: http://focus.ti.com/docs/prod/folders/print/msp430f2013.html
http://focus.ti.com/docs/prod/folders/print/msp430f1612.html
http://focus.ti.com/docs/toolsw/folders/print/ez430-f2013.html

Aerocomm:
http://www.aerocomm.com/rf_transceiver_modules/ac4486_868mhz_rf_transceiver.htm

Freescale:
http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=MPXY8021A&nodeId=0112699036ZBhH

European Radiocommunications Office frequency information system: http://www.efis.dk/

International Telecommunication Union (UTI) Radio Regulations: http://www.itu.int/publ/R-REG-RR/e