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Method to measure the tractor operation parameters from CAN BUS

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ABSTRACT

The market of the agricultural machineries has been recently modified due to globalisation, with an increasing of the competiveness and machinery reliability, and a reduction of cost production and development time. To perform this and, in particular to increase the reliability of the tractor, a tractor design correspondent to the real use on the machines is necessary. For these reasons the analysis of the tractor mission profile is one of the main objectives of tractor manufacturers. The mission profile of the tractor has usually been estimated through the use of questionnaires submitted to consumers followed by the monitoring of some detailed parameters using transducers specifically fitted on the tractor. This procedure is time-consuming and not totally reliable due to the trustworthiness in the questionnaire compilation. In all the high power tractors numerous transducers are fitted to monitor some parameters to optimise the operation of the machine. All of these transducers are connected to an electronic central unit or with the tractor CAN-Bus. In this context, a system able to monitor the operation and use parameters of the machine capitalising the existing transducers could represent the optimal solution for monitoring a high number of tractors, distributed in different regions. The high number of signals are in any case difficult to be memorised without a high quantity of memory. The goal of the paper is to define a methodology to memorise the operation parameters useful to define the mission profile of a tractor using a small memory. A tractor of a nominal power of 170 kW was selected and a system able to measure the signals acquired by the transducers fitted on the tractor was connected to the CAN Bus of the tractor. To reduce the memory requested to store the signals, all the signals were converted on matrices, with a similarly procedure used in the analysis of the strain gauge signals. In this way it is possible to count the number of occurrences for each event as the number of hours of tractor use, the number of hours for each gear use, etc. After a detailed analysis of the parameters measured on the tractor, the useful parameters were defined and acquired during 1000 hours of tractor use in different working conditions.

The method defined in the paper has allowed to store the defined time of about 1000 hours into 100 kB, instead of 24 GB required to memorise all the parameters acquired by the transducers. The analysis of the parameters stored in the memory has allowed a detailed analysis of the operational parameters of the tractor in different applications.

These parameters could be used by the engineers to design tractors with a higher quality and reliability and also to define predictive maintenance criteria and reduce the unexpected tractor failures.

Keywords: CAN-Bus, Durability, Tractor, Customer Correlation, Tractor Usage, Mission Profile, Italy

1. INTRODUCTION

The farmer's need to optimise production has induced tractor manufacturers to develop more and more specialised machines with a high product diversification. All of this has increased competitiveness between manufacturers, with a consequent increase of tractor reliability, a reduction of development costs, and time-to-market.
Reliable tractors can be built only if designed to sustain loads really recorded during the use of the machine on field from different farmers (Strutt & Hall, 2003). These loads are determined through a recording of the signals obtained from defined transducers fitted on a specific tractor (Ledesma, Jenaway, Wang, & Shih, 2005). In this way, however, the measurements are time-consuming, expensive, and often not reliable due to the impossibility to measure the loads obtained with a high number of tractors and a low measuring time with respect to the whole useful life of the machine (Socie, 2001). The load variability is in any case high due to different effects. The most relevant effects are the driver (Socie & Pompetzki, 2004), the application of the machine (Mattetti, 2012), and the market. A poor evaluation of the loads has, as a consequence, the use of higher safety coefficients with an increase of production costs, the design of tests not able to reproduce real working conditions, and an underrate of the loads with consequent problems like errors in engine mapping. These problems have been addressed using questionnaires to define the main use frequency of the tractor from the drivers (Dressler, Speckert, Müller, & Weber, 2009). The questionnaires allow to define a mission profile of the vehicle, to produce a sample of accurate measurements able to better reproduce the real life of the tractor and, therefore, to supply a useful instrument to the designers. However, the information obtained with the questionnaires is subjected to imprecise evaluations (Hayes, 2008). A more detailed evaluation of the mission profile of the machine components has been obtained through the monitoring of some parameters of one or more vehicles with the goal to define the use of some components such as the transmission or the engine (Marchesani, Parmigiani, & Vianello, 1992) or to use these parameters in simulation software (Willmerding, Häckh, & Berthold, 2001). The methodology requires the installation of a specific instrumentation consisting of external transducers, that limits the number of usable machines and, as a consequence, the accuracy of the estimation of the mission profile. These problems could be overcome through the use of a data-logging system integrated on the machine able to monitor the functional parameters of the vehicle. In different vehicles, transducers necessary for vehicle operation are mounted. These transducers are usually connected to

the CAN-Bus introduced by Robert Bosch, in 1986, to reduce the number of connections from the different electrical devices, increasing the strength of the connections and reducing the costs (Emadi, 2005). The transducers connected to the CAN-Bus have been used to measure the functional parameters of different vehicles (Mueller, Daily, & Papa, 2012) and have also been used to acquire the load spectrum in automotive transmissions (Willmerding & Häckh, 2007). With reference to tractors, on the contrary, data-logging systems have been used to measure only field work performances (Al-Suhaibani & Al-Janobi, 1996; Culpepper, 1979) without the evaluation of the mission profile of the machine. With reference to the mission profile of the tractor, previous studies have highlighted the necessity to exactly evaluate the idle time without a request of power from the engine (Mattetti, Molari, & Sedoni, 2012). The work cycle of the tractor could be acquired using transducers connected to the CAN-Bus, however, a high dimension memory would be required, but it would be difficult to fit it on a commercial tractor. The goal of the paper is to define a methodology to acquire, rework and memorise the operation parameters useful to define the mission profile of a tractor or a subsystem using a small memory.

2. MATERIAL AND METHODS

The measurements were performed on a CNH T7030 tractor with a PTO nominal power of about 116 kW. The main characteristics of the tractor are reported on Table 1. The model was selected in this range of power due to the high number of transducers connected to the CAN-Bus.

Table 1: Tested tractor specifications

Engine type	6/vertical in-line, 6728 cm³, super charged, Tier III
Power [kW]	116
Width [mm]	2234
Wheelbase [mm]	2730
Front wheel type	600/65 R28
Rear wheel type	710/70 R38
Total mass [kg]	8115
Load on the front axle [%]	40
Transmission type	Powershift with 19 forward and 6 reverse speeds

The tractor was used by a farmer located in the Emilia Romagna Region during one year for 1000 hours of work. The signals were read from the CAN-Bus using the data logger Vector CANcaseXL log (https://vector.com) and memorised on a SD card. The signals were then sampled at the CAN sample rate, converted through the software Vector CANalyzer (https://vector.com) and analysed through the software Matlab (http://www.mathworks.com). To memorise the operational parameters using a reduced memory, the data were clustered in matrices as performed with strain gage signals (Downing & Socie, 1982). In function of the signal type, the data were transformed in a

univariate histogram through the “hist” command of Matlab, or converted on a bivariate histogram matching different signals.
Between the different signals monitored, the channels correspondent to the gear selected, the PTO speed, and the engine torque, were analysed. In particular, the combination of the signals to evaluate the durability target of some tractor components, were evaluated. Previous studies have highlighted the necessity to evaluate with more precision the time without power request (Mattetti, Molari, & Sedoni, 2012). For this reason, the time of use of each gear was evaluated. But from the point of view of the engine stress, an evaluation of the PTO use (i.e. to move agricultural machineries) is also necessary. Finally, the torque distribution on the different gears was evaluated to define the load level on each gear to evaluate if other loads were used (i.e. a hydraulic load). The data were also normalised with respect to the relative frequency to compare the signals of different durations.

3. RESULTS AND DISCUSSION

In Figure 1 the use distribution of the different gears was reported.

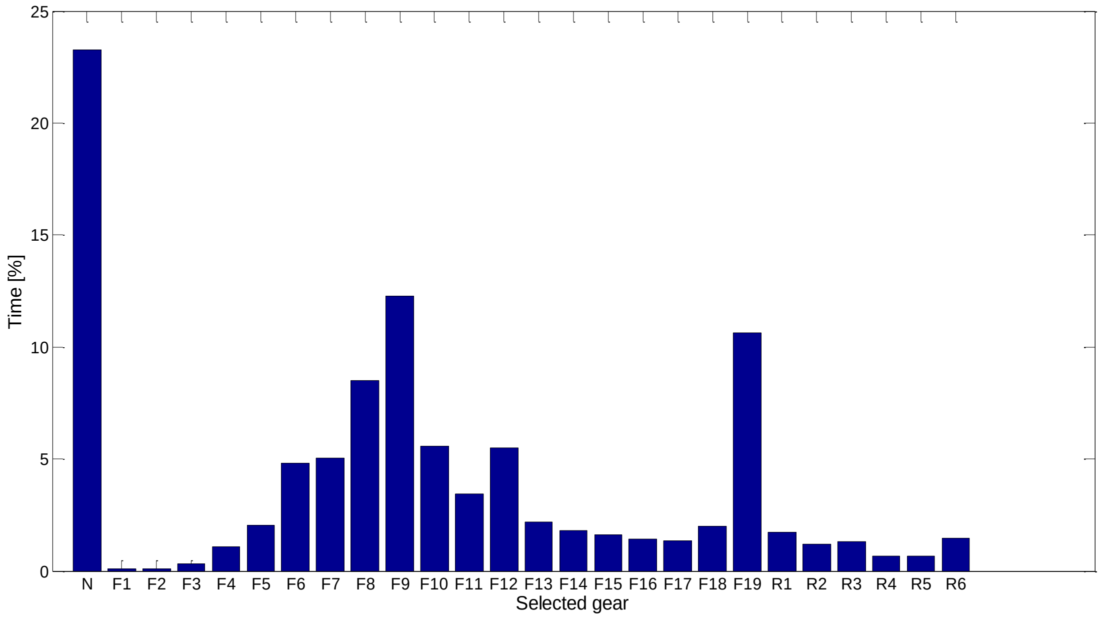

Figure 1 : Gear usage histogram

The percentage of time in neutral is higher with respect to the other gears. The tractor analysed was maintained in neutral for a percentage higher than 20% of the whole time. This is related to a situation with the tractor turned on without request of power (i.e. a condition of implement replacement or the use of the air conditioning), but also with operating machineries connected to the tractor with power request (i.e. a mill or a unifeed). The F9 and F19 gears were used for more than 10% each. The F9 gear is normally used for work on field, the F19 gear usually used for transportation. In Figure 2 the trend of the use of the PTO in the different gears is reported.

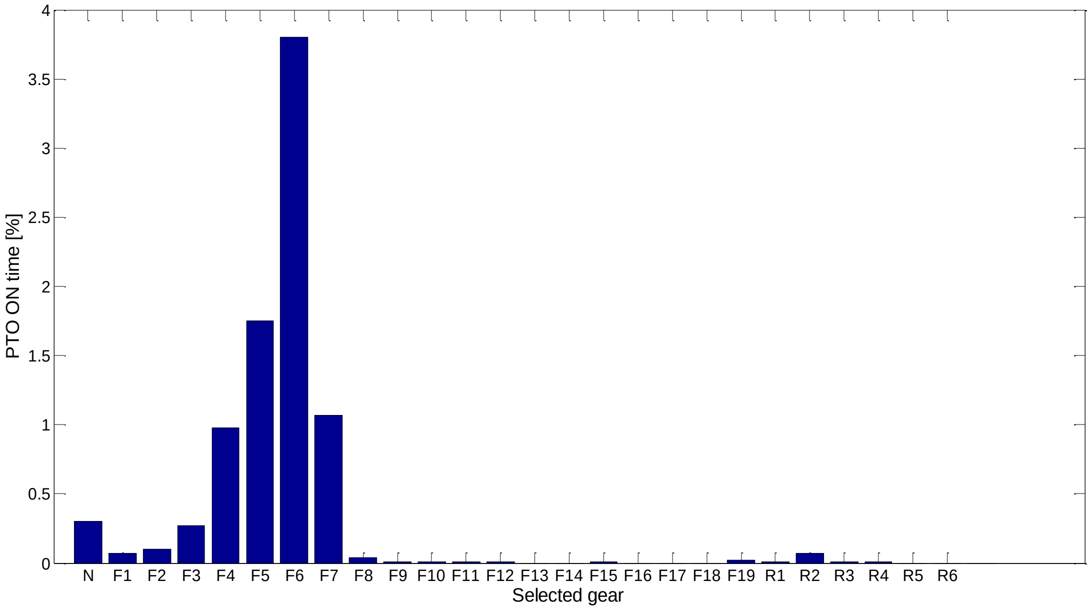

Figure 2: Use of the PTO in the different gears.

The data reported in Figure 2 show how the tractor worked with the PTO activated and the gear in neutral for a very reduced time. For this reason, the tractor was used in neutral without a power request for a percentage of time of about 20% of the yearly use. The gear used most frequently with the PTO is the F6 gear, normally selected with an operating machinery such as a power harrow. The F9 gear, used for a high percentage of time on the field without the use of the PTO, has been associated to the use of a plow.
In Figure 3 the distribution of the torque in the different gears is reported.
The spectrum of use of the torque insubstantially uniform, with a peak of about 20% for the neutral in the minimum range of the engine torque and of about 10% for the F19 in the minimum range of the engine torque.

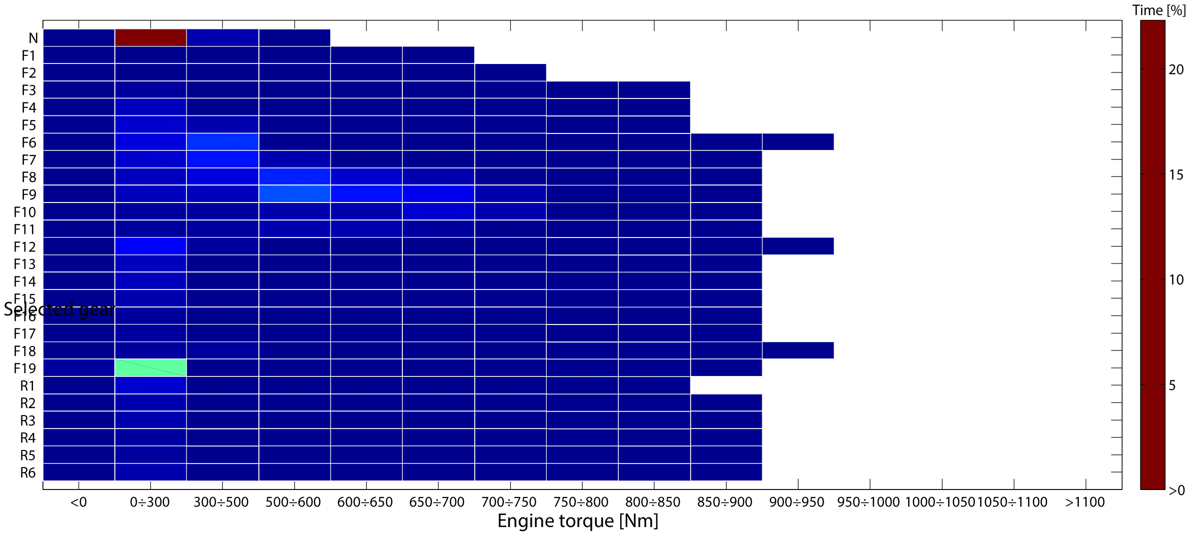

Figure 3: Engine torque measured in the different gears.

4. Conclusions

In this paper a methodology to record a large quantity of information on tractor use has been presented using a device than could be fitted on any produced tractor with an easy and quick procedure. The information acquired has been reworked with adequate statistical methods to identify some uses of the machine.
The methodology has permitted to obtain substantial information on the use of the specific machines in their real use, shown as an example, a use higher than 20% of the time in the neutral position without the use of the PTO.
This information could be used from the designers to define suitable targets for each component. The data obtained from the analysis could be employed to obtain a better prediction of the simulation subsystems of the vehicle and to optimise their performances.
Finally, this information could be used to correctly calibrate the functionality of the after-treatment device. The possibility of the farmers to identify the use of the tractor to optimise the performance and the costs is not negligible.
The activity will be extended to other signals not considered in the present work, as those connected with the three point hitch use. Other combinations useful to identify the degree of use of these machines to increase reliability will also be defined.

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