Monitoring of the tractor working parameters from the CAN-Bus

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Abstract

The analysis of the tractor mission profile is one of the main objectives for tractor manufacturers. The mission profile has usually been estimated through the use of questionnaires submitted to consumers. 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 machines. 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 working parameters of the machines capitalising the existing transducers could represent the optimal solution for monitoring tractors distributed in different regions. The high number of signals are in any case difficult to memorise 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 230 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. After a detailed analysis of the parameters measured on the tractor, the useful parameters were defined and acquired in different working conditions. 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 engineers to design tractors with a higher quality and reliability and also to define predictive maintenance criteria and reduce unexpected tractor failures.

Introduction

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 and Hall, 2003). These loads are determined through a recording of the signals obtained from defined transducers fitted on a specific tractor (Ledesma *et al.*, 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 and 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 *et al.*, 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). 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 *et al.*, 2012) and have also been used to acquire the load spectrum in automotive transmissions (Willmerding and Häckh, 2007). With reference to tractors, on the contrary, data-logging systems have been used to measure only field work performances (Al-Suhaibani and 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 *et al.*, 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.

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Materials and methods

The measurements were performed on a CNH T8.360 tractor with a PTO nominal power of about 229 kW. The main characteristics of the tractor are reported on Table 1. The model was selected in this range

Table 1. Tested tractor specification.

Engine type	6/vertical in-line, 6728 cm^3, super charged, Tier III
Max power [kW]	229, 263 with powerboost
Width [mm]	2235
Wheelbase [mm]	3450
Front wheel type	420/90R 30
Rear wheel type	710/70R 42
Total mass [kg]	12100
Load on the front axle [%]	36
Transmission type	Powershift with 19 forward and 4 reverse speeds

of power due to the high number of transducers connected to the CAN-Bus.

The tractor was used by a farmer located in the Emilia Romagna Region in different working conditions : trailer transportation, cultivation and ploughing. Each work was executed for one hour. 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 and the engine torque percentage, 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 *et al.*, 2012). For this reason, the time of use of each gear was evaluated.

Results

In this paper the results of one working condition is reported, and in particular the distribution of the different gears used during the use of a disc cultivator is reported in Figure 1.

The distribution of the used gears show how the gear F9 is the one most used during the work with the cultivator. The percentages of use in the other gears are reduced. Also the percentage of use in the neutral position is very low. All the other gears and the neutral position were used during the end field manoeuvres.

In Figure 2 the engine torque distribution in the different gears is reported. The tractor was mainly used with an engine torque between 70 and 80 % of the maximum torque. The value of the torque in the neutral position is very low with a correspondent absence of power request in the neutral position.

In Figure 3 the time distributions of the transmission in neutral position are reported. Only two intervals with the transmission in neutral position are highlighted, both with a duration lower than 30 s, probably due to the start and stop procedures.

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 infor-

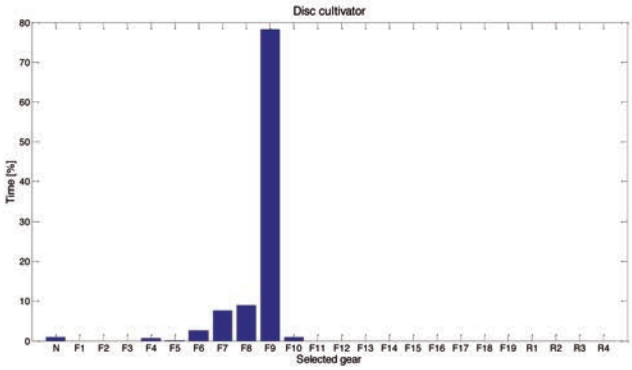

Figure 1. Gear usage histogram.

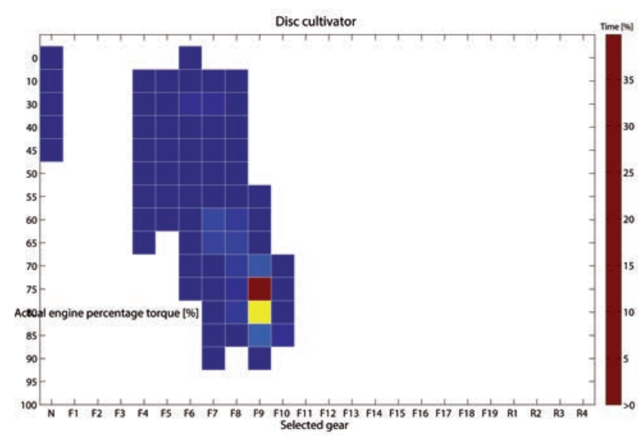

Figure 2. Engine torque used in the different gears.

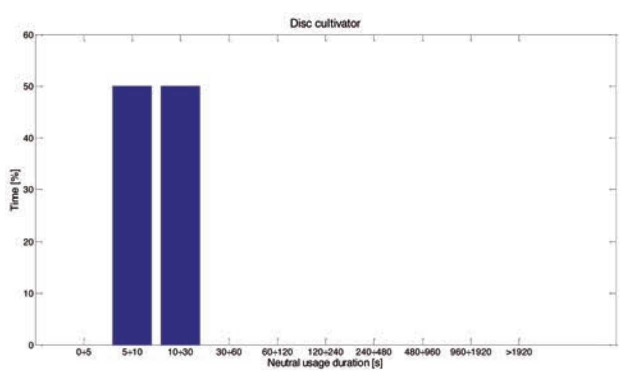

Figure 3. Neutral usage duration of the transmission in neutral position.

mation acquired has been reworked with adequate statistical methods to identify some uses of the machine.

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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