Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/issn/15375110

Research Paper

Methodology to analyse farm tractor idling time

Daniela Perozzi [a], *Michele Mattetti* [a], *Giovanni Molari* [a,*], *Eugenio Sereni* [b]

[a] *Department of Agricultural and Food Sciences, University of Bologna, viale G. Fanin 50, 40127, Bologna, Italy*
[b] *CNH Industrial Italy, viale delle Nazioni, 55, 41122, Modena, Italy*

ARTICLE INFO

Article history:
Received 26 March 2016
Received in revised form
11 May 2016
Accepted 16 May 2016
Published online 9 June 2016

Keywords:
Tractor
Idling
Customer correlation
Transmission usage
Engine

Actual in-service damage to tractor engines could be different from that predicted according to other estimates due to the difficulties in evaluating all the information necessary to completely define the mission profile. Among the different parameters which could be measured or estimated, the idling duration is one of the most influential factors in the calculation of in-service damage. In this paper, a methodology to estimate the idling time from signals recorded through a data logger interfaced to the vehicle-bus is proposed. Through statistical methods, the idling duration distribution was identified for a fleet of 61 New Holland T9 farm tractors used in Europe and in North America. Starting from these distributions the percentiles have been estimated. The recorded values of idling duration range from 5% up to 50% and the average value is about 20% of the tractor life. Furthermore, 97.5% of the analysed tractors run under idling condition for greater than 10% of the whole life of the machine. All tractors have made at least a stop shorter than 1920 s, while not all have made a stop longer than 1920 s. From the analysis, tractors located in areas with extreme temperatures have run under idling conditions for a longer time to keep the cab comfortable or to maintain the engine on temperature. This data confirms the importance to considering the geographical distribution of the machines and the necessity of performing a wide acquisition campaign to define the tractor mission profile.

1. Introduction

One of the characteristics most considered by the purchasers of commercial vehicles and agricultural machines is their durability, defined as the capacity of a machine or a component to maintain the functionality during its design life (Johannesson & Speckert, 2013). In the past, agricultural machines were designed using high safety coefficients with the obvious consequence of designing excessively heavy and expensive machines (Harral, 1990) resulting in high fuel consumption for the higher soil compaction (Molari, Bellentani, Guarnieri, Walker, & Sedoni, 2012; Molari, Mattetti, & Walker, 2015). Nowadays, this approach is no longer sustainable in a competitive market in which manufacturers are obliged to reduce the development and production costs and to design machines for different markets (Garcia, Araan, & Ruiz, 2010). For these reasons, the customer correlation, a methodology to design new products in relation to their real usage by customers, has been introduced in recent years (Strutt & Hall, 2003). This methodology has permitted the test targets of many manufacturers to be

* *Corresponding author*. Tel.: +39 051 2096191; fax: +39 051 2096178.
E-mail address: giovanni.molari@unibo.it (G. Molari).

http://dx.doi.org/10.1016/j.biosystemseng.2016.05.007

improved both by setting the testing load conditions closer to the service ones and by using a test bench able to reproduce tractor dynamics during field operating conditions (Mattetti, Molari, & Vertua, 2015; Thomas, Perroud, Bignonnet, & Monnet, 1999). Thus, the tests designed with this methodology are able to apply to the structure damage equivalent to that experienced in service (Lee, Pan, Hathaway, & Barkley, 2005).

Precise knowledge of the load cycle amplitudes and the number of their occurrences is necessary to design the structural components of a machine to reproduce the same damage as induced by the use of the machine in the whole life. This information cannot be simply calculated from the lifetime of machines (Socie & Pompetzki, 2004), because of the inactivity duration that reduces the number of cycles accumulated by the structure during the service life and, as a consequence, the accumulated damage (Mattetti, Molari, & Sedoni, 2012).

Idling time is considered as an operating condition in which the engine is not subjected to any substantial load and the tractor is not moving. This can be a short-term condition, for example during headland turns, or a medium-term condition, as during implement changes or during specific activities such as the support of combines during cereal discharge into a trailer. In other cases idling can be a long-term activity such as the retention of the comfort level inside the cab or the engine temperature to the optimal thermal conditions, especially in colder regions where a common practice is to let the engine idle during the night (Lutsey, Brodrick, & Lipman, 2007; Surcel & Jokai, 2011). Extended idling periods may damage the engine (Brodrick, Dwyer, Farshchi, Harris, & King, 2002) and the exhaust after-treatment system (Michelin, Figueras, Bouly, & Maret, 2000). However, the study of idling conditions has been limited to the evaluation of fuel consumption and pollution emissions (Bietresato, Calcante, & Mazzetto, 2015; Gaines, Vyas, & Anderson, 2006). Recording idling duration is a difficult task especially if an accurate statistical analysis is required, because duration has to be measured under real customer usage from a fleet of vehicles for almost an entire year (Christopher Frey, Kuo, & Villa, 2008).

The measurement of the idling duration of tractors, with respect to other vehicles, cannot be simply derived from the time spent in the neutral gear due to the fact that tractors are often used as stationary machines. Therefore, the detection of idling conditions requires also the instantaneous value of the engine torque. These measures could be obtained by fitting specific sensors on a machine sample, however this solution would not allow a fleet of vehicles to be monitored simultaneously due to sensor costs and the weak durability of their connections during a prolonged field usage (Pompetzki, Dabell, Gothamy, & Bechtel, 2009). These problems can be overcome by acquiring idling data through the vehicle embedded sensors installed on modern tractors to control the different subsystems of the machine. Embedded sensors allow the acquisition of information on the use of a wide sample of vehicles by simply installing on-board data loggers (Ludes & Steeples, 1999). The data obtained could then be used to derive a mission profile that is more damaging than that of a defined percentage of the tractor population (Ensor & Cook, 2007) and thus to define design targets of specific components which avoid their overdesign (Campean & Brunson, 2000).

The goal of this paper is the definition of a methodology aimed to acquire the information to calculate idling duration using embedded sensors in tractors and to analyse the characteristic parameters through statistical methods.

2. Materials and methods

The methodology outlined in this paper has been applied to a tractor family, namely New Holland T9, with the specifications reported in Table 1.

A sample of 61 tractors was selected, of which 54% were used in Europe (EU), equally divided between east and west, and 46% in the North American Region (NAR), mostly in the USA with the others in Canada. Tractors were monitored for a whole year (with an average of about 800 h of work) to avoid the influence of the seasonality of tractor working. An autonomous data logger, able to store the data coming from the different embedded sensors, was installed in each tractor. The signals of the selected gear and engine torque were acquired, both sampled at a frequency of 50 Hz. Idling condition was detected as the instance where the tractor transmission was in neutral and the engine was run at a torque lower than the 12% of the maximum torque delivered from the engine of each tractor. To have a homogenous sample, the idling duration values of each tractor were scaled to the actually worked hours of the machine.

The data obtained in this way has been divided into three groups: tractors of the global market (AM), tractors of the NAR market and tractors of the EU market. For each group, the sample mean (Mean), the standard deviation (SD), the Skewness index (β1), the Kurtosis index (β2), and the variation coefficient (β3) were calculated with the goal of evaluating the shape of the distribution that was best able to fit the data (Rees, 2000).

The distribution of the AM group was evaluated with the chi-square test (χ^2). For the groups NAR and EU, the distribution was evaluated with the Shapiro–Wilk test because there were less than 50 samples each (Rees, 2000). All the tests were executed applying a significance level equal to an error of 5% for each group. The distribution with the lowest Bayesian Information Criterion (BIC) in absolute value (Burnham & Anderson, 2002) was chosen, then the parameters of the distribution were estimated and the 2.5th and 97.5th percentile was respectively calculated.

To better describe the idling usage of tractors, idling stops were binned into the following intervals: 0–5; 5–10; 10–30; 30–60; 60–120; 120–240; 240–480; 480–960; 960–1920; and >1920 s. The nonlinear bin width was chosen in order to divide the short stops with respect to the long ones. The average, maximum, minimum, and relative box plots (with outliers)

Table 1 – Tested tractor specifications.

PTO power [kW]	430–500
Max engine torque [Nm]	1760–2516
Mass [kg]	15,042–20,134
Transmission	Powershift: 17 FWD, 2 RWD