DEVELOPING SOFTWARE TO ANALYZE THE POINT AND FUEL FOR AGRICULTURAL TRACTORS

A. Soto Otalora[1] and H. R. Salas Ramirez[2]
[1]Industrial Automation, Surcolombiana University Neiva, Colombia
[2]Department of Electronics Engineering, Surcolombiana University Neiva, Colombia
E-Mail: agussoto@usco.edu.co

SUMMARY

The work involves the development of software able to calculate tractor data such as Power Take off (PTO) and Fuel consumption based on studies related to test Nebraska. The reason that motivates the development of this project is that it is necessary to know in greater depth certain characteristic tractor data in order to gain a deeper understanding of the behavior of this in works like tilling soil and under different conditions as to power requirements and fuel consumption, so that it can give greater control to the use of this carrying an analysis on the data produced by the program. The software develops mathematical calculations based on certain known data which are provided by the manufacturer of the tractor to be assessed. The program processes the data and throws us numerical results and in most cases representative graphs that help us analyze the behavior of certain features of the tractor as are PTO and Fuel consumption; data that help us predict the behavior of the tractor in certain specific jobs, it provides the possibility to know the fuel consumption and costs generated in this work.

Keywords: power take Off, Nebraska test, fuel consumption.

1. INTRODUCTION

Today, with technological advances by leaps and bounds, computer programs are a very dynamic and high-growth area in the ICT sector.

However, despite the progress of recent years, it is necessary to design and implement programs that are able to improve living conditions and to facilitate the learning process of human beings in different areas of knowledge.

This way you can successfully address the problems that arise in a world where constant improvements are required in both software and hardware of different farming systems, with the aim of providing quality service to users and in turn ensure that such information is processed and stored in a reliable way.

In agriculture has always been necessary constant monitoring of the work already done in turn is essential to take complete control of the proper management of agricultural equipment, this process has always evolved at the same time it has done various branches of technology. As you can see through history, when the technological age was in its infancy many agricultural processes were manual and controls was rudimentary and often were unreliable, however, as the technology was gaining strength also I was doing the agricultural area where the monitoring process by automating were in different agricultural areas by using sensors, automatic recording, analysis software, among others.

Experimental Farms currently perform different tasks for development of mankind in agriculture. For this reason it is necessary that always is monitoring the work of agricultural machinery of the place and one of the most important is the tractor, which is used in many of the daily tasks that are done on a farm, for example, soil tillage and possible variants that arise, giving the possibility of making work more efficiently to have more information which helps to better performance of those tasks with the lowest possible cost.

The software performs mathematical calculations developed from certain known data which are provided by the manufacturer of the tractor to be assessed. The program processes the data and throws us numerical results and in most cases graphic representative to help us analyze the behavior of certain features of the tractor, data that help us predict the behavior of the tractor in certain specific jobs, besides providing the possibility to know the fuel consumption and costs generated in this work.

2. RATIONALE

2.1 Test of Nebraska

The laboratory at the University of Nebraska (NTTL) is officially designated as the test station in United States of tractors economy according to the Organization for Cooperation and Development (OECD) under OECD codes. But now tractors are tested in their country of manufacture under standards developed at the University of Nebraska. There are currently 29 countries that are governed by the OECD code of which 25 are members and 4 no.

Nebraska test allows farmers to know exactly tractors information so that when you purchase one of these choose the one that best suits your needs.

The most important thing you should know about this test is that the results are based on actual tests, this means that the test is not subjective. The reports did not say whether the cabin is comfortable or if the controls are easy to use. The intention of this test is to provide mechanical and performance tractors minimum and maximum, i.e. numbers and more numbers features. This allows a clear comparison between different models of tractors considering variables such as work to be performed and the different types of soil which can be found and in turn adapt, which is an objective test.

As mentioned above reports and graphs are numbers that define me occasionally horsepower, torque, fuel, hydraulic system, towing capacity, dimensions, power bar, among others.

The difference between test levels are optional, meaning that you can adapt your test results to the level you want according to your needs work

Some of the levels reports can be:

Specification Test: This test verifies the measures and specifications to be sure that everything is consistent with factory specifications.

Test Condition: engineers record the exact Tractor test conditions to ensure that these conditions meet the requirements of the test procedure.

Test required: recording engineers tractor performance to the average power in the different aspects involved in this, also they include bar tests, test shooting and making fuel consumption.

Graphics: Numerous graphics available in reports to give readers a better reference when looking at data like pulling power (PTO) and fuel consumption. [1]

2.2 Tractor power ratings

The different powers of the tractor are used to assess the size of tractors and engines. This is important because knowing the different powers of the tractors at their highest values enables comparison and therefore their competition in today's market.

It is important to know that power usage is usually less than the maximum power test. Units to express the power must be known before determining the power recommended use. The following figure shows the power of the tractor and its location in thesame at the time of testing. [2]

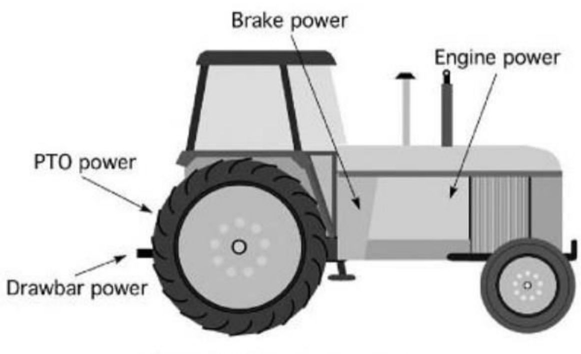

Figure-1. Tractor power features.

2.3 Power take off

The Power Take off (PTO) is data derived from the pulling power of an agricultural tractor. Shot powers are used to supply rotational power to various machines such as presses, pumps and cutters.

In the case of an agricultural tractor that power is taken from the engine rotational force, i.e. engine torque.

The following image shows the gear of an agricultural engine which pulling power (Power Take off) is taken.

Figure-2. PTO (PTO) at the rear of an agricultural tractor.

We can determine the power (PTO) of the tractor by agricultural the following mathematical equation which is expressed as follows:

$$\text{Power (Hp)} = \frac{ToxN}{5252}$$

Where:

To = Torque (lb-ft)
Hp = Power in horsepower
N = Speed (RPM)

Or by this other expression in SI system:

$$\text{Power (kW)} = \frac{To \ x \ N}{9549}$$

Where:

To = Torque (Nm)
kW = power Kilowatts
N = Speed (RPM) [3]

2.4 Fuel consumption

Fuel consumption is perhaps one of the most important variables that must be taken into account when analyzing the performance of an agricultural tractor in the different conditions of fieldwork that may arise as through good management of data fuel consumption we can handle what is known as operating costs which depend on more than 80% of fuel consumption.

Fuel consumption is measured as the amount of fuel used over a period of time. The most common measure of energy efficiency in a tractor reference fuel is the specific volumetric consumption (SVFC English Specific Fuel Consumption) which occurs in the L / kW-hr units for the international system or gal / hp-hr for the English system. Usually the specific volumetric consumption is not affected by engine size but these measures serve to compare the efficiency of energy enter them different tractor models on the market.

Currently we can estimate the fuel consumption under the ASAE (Agricultural Machinery Engineering Management) standards according to their respective sections 6.3.2.1, 6.3.2.1.1 and 6.3.2.1.1.2 of ASAE EP496.2. [4] According to these sections we have:

"6.3.2.1. Fuel for tractors. The average annual consumption for tractors can be used to calculate the cost of machinery for any company, however, to determine the cost of a particular operation such as plowing, fuel consumption then be based on the power requirement needed to such work. "

"6.3.2.1.1. Annual average consumption for any model of tractor can be approximated by data from the laboratory of the University of Nebraska (NTTL). Then fuel consumption can be estimated with the following expression for the international system:

$$Qavg = 0.305 \text{ x } Ppto$$

Where:

Qavg = Average Gasoline Consumption (L/hr)
Ppto = Power PTO (kW).

And with the following expression for the English system:

$$Qavg = 0.06 \text{ x } Ppto$$

Where:

Qavg = Average Gasoline Consumption (Galón/hr)
Ppto = Power PTO (Hp)."

"6.3.2.1.2. A diesel tractor can use about 73% maximum consumption of a gasoline tractor and a tractor with petroleum gas (LPG liquefied petroleum gas English) using 120% maximum."

Then based on the previous section can then deduce mathematical expressions for a diesel tractor and a tractor with LPG (petroleum) which can be seen in the following Table-1.

Table-1. Equations of fuel for tractors diesel and LPG.

System	Diesel	(LPG)
International	$Q = 0.223$ x Ppto	$Q = 0.366$ x Ppto
English	$Q = 0.044$ x Ppto	$Q = 0.072$ x Ppto

These equations are used to find the average annual consumption, and were used in the reports provided by the University of Nebraska (NTTL). Fuel consumption in tests done with variations PTO power (95%, 85%, 75%, 65%, 55%, 45%, 35%, 25% and 15% in our case) and is of as follows:

First we found the average consumption, then this value is divided by the percentage of the power test, so we find the specific consumption for a load according to data from the University of Nebraska (NTTL), however under the ASAE standard EP496.2 the 2002a has a mathematical process established on specific fuel consumption.

According to section 6.3.2.2 of the standard ASAE EP496.2 of 2002a it provides that:

"6.3.2.2 Operations that estimate the specific fuel consumption for a specific task or operation requires the full PTO power required for this operation. The PTO is then equivalent power divided by the maximum PTO power so we obtain a percentage loading for the engine. Then the fuel consumption for the cargo can be estimated under clause 3 of the ASAE standard D497. [5] Then the fuel consumption for a particular operation can be estimated under the following calculation: $Qp = Qsvfc \text{ x } Pt$
Where:

Qp = estimated consumption for a given operation L/hr o gal/hr.
Qsvfc = Volumetric specific consumption in L/kW-hr o gal/Hp-hr determined in clause 3 standard ASAE D497.
Pt = Power PTO required for a particular operation.

It is noteworthy that 15% more fuel consumption adds to reports Nebraska in order to emulate the effects of soil type, this in order to compensate for the loss of efficiency that occurs in the field work . "

Clause 3 as mentioned above speaks of:

"3.3 fuel efficiency varies by the type of fuel used and the load on the tractor. Typical agricultural tractors and tractors with hybrid engines with a load above 20% are modeled by the following equations.

The typical fuel consumption for a specific operation is given in L / kW-hr for the international system and gal / hp-hr for English system, where X of equations represents the percentage in decimal PTO power required for operation specific, which is drawn on the nominal maximum power of the tractor PTO. These equations are:

$Gasoline\ (SI) = 2.74X + 3.15 - 0.203\sqrt{697X}$
$Gasoline\ (US) = 0.54X + 0.62 - 0.04\sqrt{697X}$
Diesel:
$Diesel\ (SI) = 2.64X + 3.91 - 0.203\sqrt{738X + 173}$
$Diesel\ (US) = 0.52X + 0.77 - 0.04\sqrt{738X + 173}$
LPG (Petroleum Gas):
$LPG\ (SI) = 2.69X + 3.41 - 0.203\sqrt{646X}$
$LPG(US) = 0.53X + 0.62 - 0.04\sqrt{646X}$"

The above equations give us set an approximate fuel consumption for a specific task but not for partial load, partial load then we need to estimate these equations consumptions are shown in the following Table-2.

Table-2. Equations fuel consumption at part load.

Fuel	Ecuaciones
Gasolina	$(SI) = (2.74X + 3.15 - 0.203\sqrt{697X}\ )$*X * Ppto $(US) = (0.54X + 0.62 - 0.04\sqrt{697X})$ *X * Ppto
Diesel	$(SI) = (2.64X + 3.91 - 0.203\sqrt{738X + 173})$*X*Ppto $(US) = (0.52X + 0.77 - 0.04\sqrt{738X + 173})$*X*Ppto
LPG	$(SI) = (2.69X + 3.41 - 0.203\sqrt{646X}\ )$ *X * Ppto $(US) = (0.53X + 0.62 - 0.04\sqrt{646X})$ *X * Ppto

VOL. 12, NO. 3, FEBRUARY 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Where:
X = represents the percentage of load in decimal.
PPTO = is the nominal power of the tractor PTO.

And the result is given in L / hr or gal / hr depending on the system used. [6]

2.5 Fuel cost

It is very important and prudent before purchasing agricultural machinery and special machinery dependent on a fuel source (such as tractor), analyze the economic feasibility of it, often at some point we will find that it is better to rent machinery to buy it and vice versa. Knowing the fuel costs of machinery we are estimating 70 to 80 percent of total operating costs of the tractor, and the rest depends on maintenance costs and care of this, which are usually fixed costs, while fuel costs are always variable and depend on the work to be performed.

The cost of agricultural machinery per hour of work is strongly influenced by its use. Annual hours of use of a tractor can usually be determined by one meter hour for those occasions in which a tractor is used for different tasks, over a year, but when you have a quarterly work plan, Bimonthly or a year is not necessary, as is known in advance the hours and intensity of work for that time.

For a farm it is very important to know a priori the operating costs of a job to be performed as to carry out various research projects which thanks to proposals made by engineers and agronomists are made, it is necessary before approving a job or project looking at fuel costs that will be used for this purpose in order to analyze the economic feasibility of the project according to their duration of work.

Table-3. Duration of work with the tractor and its equivalent in hours.

Work length	hours
1 Día (Laboral)	8 Horas
5 Días	40 Horas
1 Mes	160 Horas
1 Trimestre	480 Horas
1 Bimestre	960 Horas
1 Año	1920 Horas

In the previous section we can see that unveiled the different equations that determine us fuel consumption per hour according to the needs or the work done, to know the operating costs for working time what we will do is multiply the consumption found by the price of fuel and in turn by the number of hours spent according to the following table.

2.6 Graphic interface

The analysis program has several tabs with different functions which analyze the behavior of the tractor in different working conditions so that they can analyze characteristics as tractor power, fuel consumption, fuel prices among others. This is done in order to compare the performance of a tractor with respect to others.

These data can also be stored in files which can then be used by the user for examination. In the next picture you can see one of the tabs on the developed software, which is related to fuel consumption.

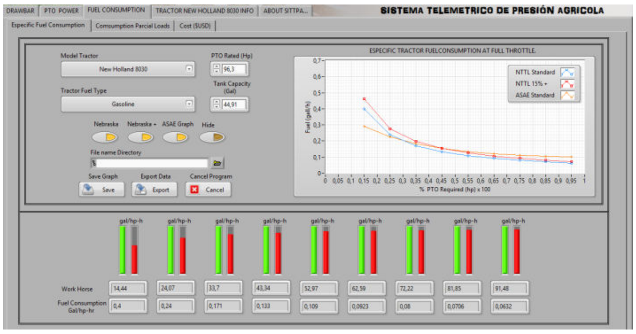

Figure-3. Graphical user interface program developed.

4. RESULTS

4.1. Analysis program

Analysis program is made by flanges which contain different analysis tools for performance of the tractor, this section provides an example of using each tab so that you can analyze the results of two tractors New Holland but will be shown different references in order to show the potential of these tools when choosing a tractor at the time of a job or even before purchasing one.

The following table lists the most important characteristics of each tractor show; also it should be clarified that being of the same make most of its features are similar.

Table-4. Series 30 New Holland tractors.

Especifications Serie 30		
Model	**7630**	**8030**
Power (Hp)	104,5 (83,6)	120,3 (96,3)
Torque (Nm)	430	490
Tank (Gal)	44,91	44,91

In this test work with two large sections of the PTO power application (power shot) and fuel consumption and its variants, specific consumption, consumption at part load and fuel costs in certain jobs. It should be clarified that the power shown above is the first to maximum power and found in brackets is the rated power, which must not be exceeded for the cycle engine life is prolonged and is about 80% of the max.

4.2 Test PTO

In this test a comparison was made of the behavior of the tractor at different revolutions which yielded interesting results which can be seen in the chart below.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

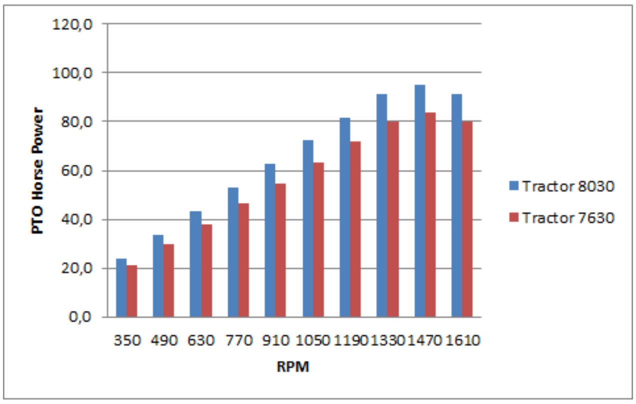

Figure-4. Comparison of the results of the test Graphic PTO.

In the graph above it can be seen that the 8030 New Holland tractor as expected has superior characteristics regarding tractor PTO refers to NH-7630.

To be more accurate the tractor NH-7630 has a 12, 20% less than the NH PTO-8030 tractor. In addition it also can be seen that both tractors reach their maximum power between 1400 and 1500 revolutions per minute (RPM), after 1600 revolutions we see a slight decrease in power shot, which tells us that after 1600 revolutions the engine starts to have flaws which makes strength is lost and therefore the life of the engine decreases, so it is advisable not to exceed 1450 rpm when using any contactor in order to maintain the engine life. The software also analyze the data also allows PTO regarding the classical rule of 86%, results discussed in the next section.

Rule of 86%

According to this rule says you can estimate a value close PTO power for agricultural tractors knowing its maximum power and 86% getting to that power. This is an approximate way of knowing that power should not have a data sheet and a tractor manufacturer has only a few data. [7]

According to that rule the data obtained are shown in the following chart.

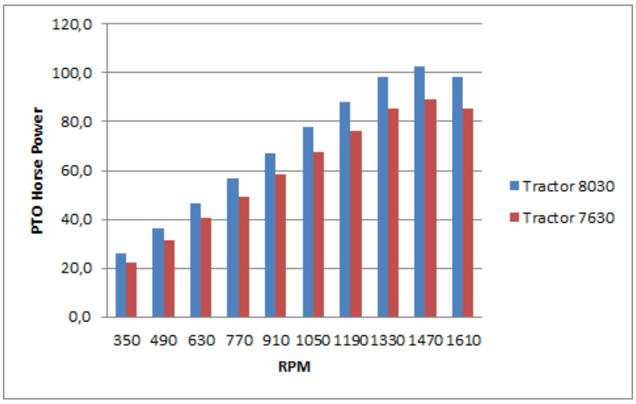

Figure-5. Comparison of the results of the test according to the rule PTO 86%.

The test results under the rule of 86% is very similar to the previous one, the NH-7630 tractor has a 13.10% less than the NH PTO-8030 tractor.

In this test we can conclude that when analyzing the numbers of tests with the two methods for each tractor we have the evidence to the NH-8030 tractor and tractor NH-7630 there is a difference of 6.9% and 6.1% between tests respectively, which can be stated that the data obtained with the rule of 86% had an error margin between 6% and 7%, which makes the rule of 86% is a good estimate of the power PTO a small margin of error.

4.3 Fuel consumption

Knowing fuel consumption is one of the most important data when looking at the cost / benefit in using agricultural machinery reason, in this test we analyze consumption low des parameters specific consumption and consumption at part load both with maximum acceleration is i.e. in optimum performance.

4.3.1 Specific fuel consumption

The specific consumption is calculated when the tractor is running without load and at full throttle. The test results can be seen in the following graphs.

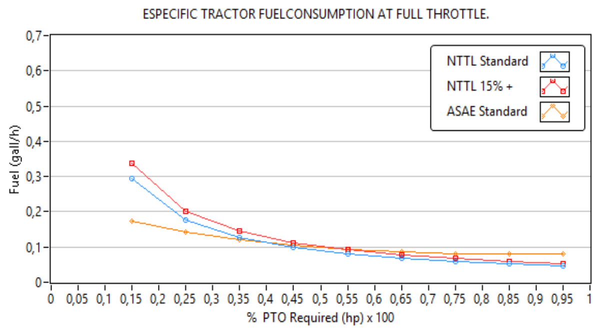

Figure-6. Specific fuel consumption tractor NH-7630.

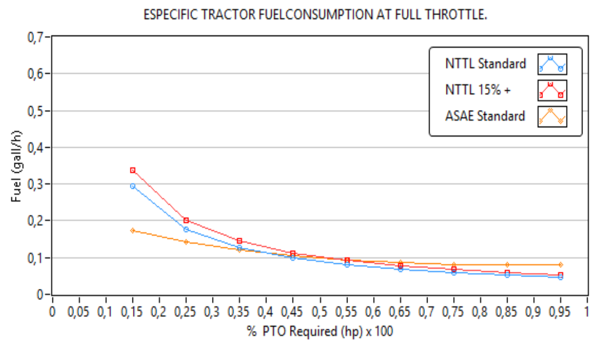

Figure-7. Specific fuel consumption tractor NH-8030.

In the above charts you can see 3 curves, each of which represents a different approach to analyze the specific consumption mathematical model, this is done in order to better analyze consumption data with as much information as you can get and what better way to get information be done under 3 different models, it should be noted that the software allows for the three curves.

The test results are clear to low power requirement the specific fuel consumption is large and the higher power consumption requirement is lower. This is because when the tractor is running at low power the tractor uses the first marches engines which are those with more force and therefore they consume more fuel, and higher power requirement gears are used speed which makes the tractor uses less fuel. This statements based on the data obtained are met not only for agricultural tractors, also met for motor vehicles such as motorcycles and cars.

4.3.2 Consumption

Unlike the previously obtained data where specific consumption is no load on the tractor, consumption at partial loads on the other hand refers to the moment when the tractor is operating at maximum load acceleration, i.e. work where the tractor must drag objects, either to move them from one place to another or either soil tillage work or related to agricultural issues. The test results can be seen in the following graphs.

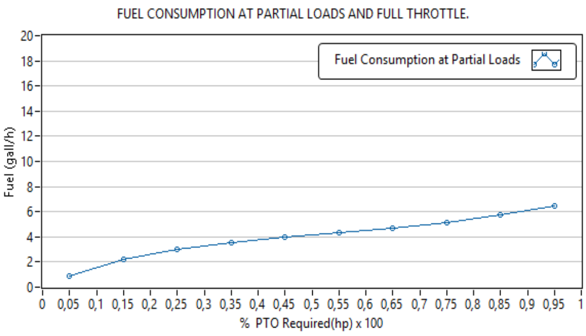

Figure-8. Fuel consumption at part load tractor NH-7630.

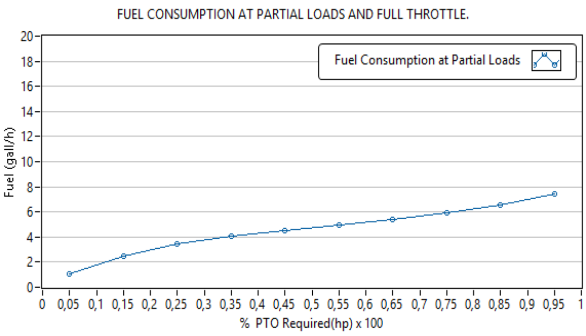

Figure-9. Fuel consumption at part load tractor NH-8030.

By observing and comparing the results we can say that fuel consumption at part load is higher in the NH-8030 tractor in the NH-7630 tractor, generally it would be more profitable to use the NH-7630 tractor for being more economical in fuel consumption NH-8030, but it should clarify that all depends on the type of work to be performed and the power requirements of work, since the two tractors which can make greater efforts is the 8030 and not 7630 then everything depends on the type of work to be done to make the right choice according to the data produced by the software.

4.4 Fuel cost

In this part fuel costs of both tractors NH-7630 and NH-8030, for a certain job where power is required specific work will be analyzed; two examples a job where the required power is 25 Hp first be raised, and another situation where the required power is 90 Hp be considered. It should be clarified that in the examples for which we use the application the following data were used, with respect to the price of fuel.

For a diesel engine fuel engine is used for this type which has a price of 7,307.03 Colombian pesos for the month of March 2016 and the dollar is around 3,150 pesos which makes about a gallon of diesel fuel have a dollar approximately 2.3 Dollars / Gal.

The results obtained by the software developed for a working power 90 Hp for NH-7630 tractor and tractor NH-8030 can be seen in the following graphs.

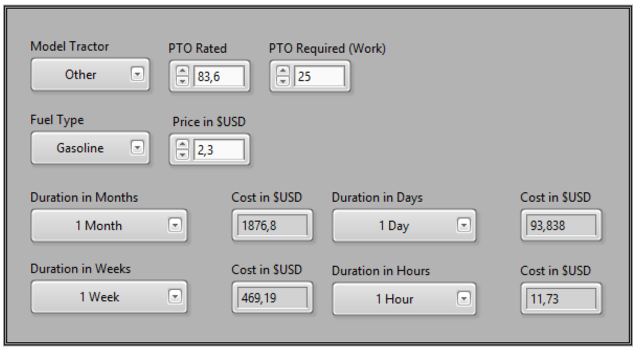

Figure-10. Fuel costs for work of 25 Hp tractor NH-7630.

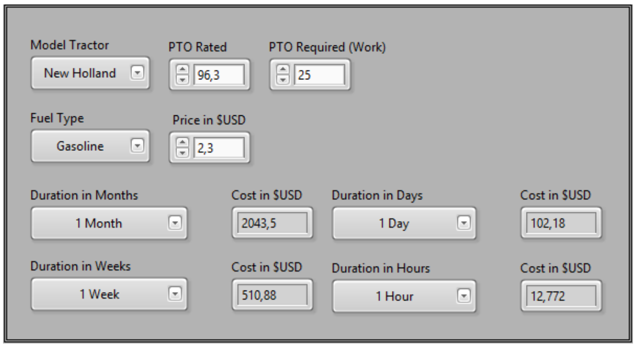

Figure-11. Fuel costs for work of 25 Hp tractor NH-8030.

According to the data obtained in the first test we can say that the tractor has lower costs for a job that requires working power of 25 Hp is the NH-7630 tractor. According to the graph the NH-7630 tractor hourly rate is $ 11.73 and NH-8030 is $ 12.72 per hour, the difference between prices is approximately $ 1 dollar, however this is a minimum time but if we analyze for example the prices of 1 month of work as seen in the pictures above the difference it is $ 166.7, money that could be used for other agricultural work, therefore this work the best tractor is the NH-7630 and the curious thing about this is that in the eyes of any NH-8030 tractor would be the favorite of many to have greater capabilities.

Now the results of the second test according to the software for a working power 90 Hp, can be seen in the following graphs.

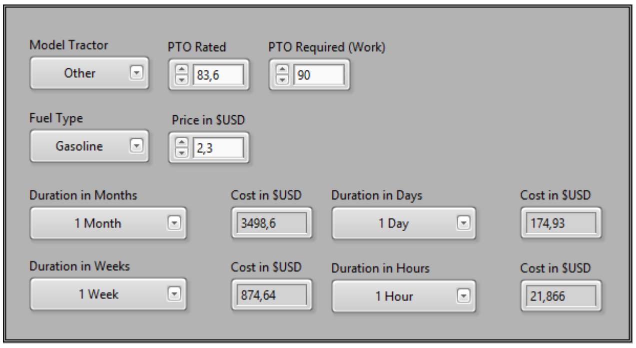

Figure-12. Fuel costs for work of 90 Hp tractor NH-7630.

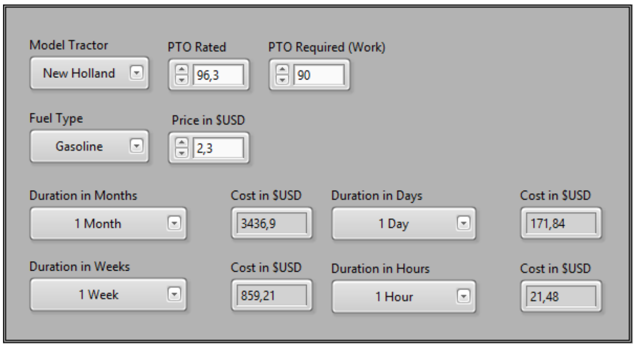

Figure-13. Fuel costs for work of 90 Hp tractor NH-8030.

According to the data obtained in the second test we can say that the tractor has lower costs for a job that requires working power of 90 Hp is the NH-8030 tractor. According to the graph the NH-7630 tractor hourly rate is $ 21.86 and NH-8030 is $ 21.48 per hour, the difference between prices is approximately $ 0.38 cents, is very little difference to the naked eye, but if you look for instance prices of 3 months of work, the difference would be $ 185.1, money that could be used for other agricultural work, therefore this work the best tractor is the NH-8030, but let's remember one thing although the difference is small if we analyze the work required is 90 Hp, with test results PTO miss above, you can also see that the NH-7630 tractor even though you can make this work, I find working in an area of "forced" labor; i.e. could fulfill tasks of the power requirement, but would be forcing the engine, which would reduce its useful life, which would lead to an engine failure in the medium term if such work is developed for prolonged periods. Therefore the best tractor for this work is the NH-8030 tractor.

5. CONCLUSIONS

Software which provides reliability and security when calculating data is successfully developed, also allows the storage of these files easily accessible. These files are of two types one graphic and other numerical, which facilitates the interpretation and analysis of the data produced by the software allowing to compare data from different tractors and this makes possible the choice of the tractor that best suits the user needs leveraging its efficiency and reducing costs (fuel) operating.

According to the PTO test we can conclude that when analyzing the numbers of tests with the two methods for each tractor we have the evidence to the NH-8030 tractor and tractor NH-7630 there is a difference of 6.9% and 6.1% between tests respectively, with which it can be said that the data obtained with the rule of 86% had an error margin between 6% and 7%, which makes the rule of 86% is an estimate good power PTO with small error margin.

The test results of specific fuel consumption are clear to low power requirement the specific fuel consumption is large and the higher power consumption requirement is lower. This is because when the tractor is running at low power the tractor uses the first marches engines which are those with more force and therefore they consume more fuel, and higher power requirement gears are used speed which makes the tractor uses less fuel. This statements based on the data obtained are met not only for agricultural tractors, also met for motor vehicles such as motorcycles and cars.

By observing and comparing the results of the test consumption at partial loads can say that fuel consumption is higher in the NH-8030 tractor in the NH-7630 tractor, generally it would be more profitable to use the tractor NH-7630 by being more economical in fuel consumption NH-8030, but should clarify that all depends on the type of work to be performed and the power requirements of work, since the two tractors which can make greater efforts is the 8030 and not 7630, then everything depends on the type of work to be done to make the right choice according to the data produced by the software.

In the case of fuel costs the software is ideal for cost projection projects and jobs that require the use of agricultural tractor, this in order to know a priori the costs generated when performing certain types of work, thus providing more information when choosing agricultural machinery, which better suits the user's needs and budget that this has meant for this work.

REFERENCES

[1] 2005, Research Update Standardized Tractor Performance Testing (What It Is - and Isn't). Obtained from: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/eng9922/$file/727.pdf?OpenElement.

[2] Introduction to Agricultural engineering technology. Third Ed. p. 82.

[3] Introduction to Agricultural engineering technology. Third Ed. p. 83.

[4] ASAE Standards, 49th Ed. 2002a. EP496.2. Agricultural machinery management. St. Joseph, Mich.: ASAE.

[5] ASAE Standards, 49th Ed. 2002b. D497.4 JAN98. Agricultural machinery management data. St. Joseph, Mich.: ASAE.

[6] Predicting Tractor Fuel Consumption Robert D Grisso, Michael F. Kocker y David H. Vaughan. (Universidad de Nebraska - Lincoln).

[7] Harry L. Field, Lawrence O. Roth. 2012. Introduction to Agricultural Engineering: A Problem Solving Approach. p. 69.