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Assessment and equipment of parameters of MF399 Tractor with synthetic fuel system of Gasoline and liquid petroleum gas (LPG)

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Abstract

Gasoline is considered as the biggest source of energy in agricultural machines. In this study, MF 399 Tractor was equipped with synthetic fuel of gasoline and liquid petroleum gas in agriculture and natural resources department at university of Ramin, khozestan. This tractor was previously equipped with a data collection system. Fuel measurement system worked accurately and simultaneously stored and separated the consumed amounts. Consumed fuel, drawbar power, specific fuel and overall energy efficiency of tractor was performed on track in five synthetic fuel surfaces including 100% gasoline (D100), 80% gasoline and 20% gas (D80), 60% gasoline and 40% liquid gas (D60), 40% gasoline and 20% liquid gas (D40) and

20% gasoline and 20% liquid gas (D20) with two forward speed of 3/5 and 7 kilometer per hour factorial experimentally in completely accidental blocks. Results showed maximum gasoline consumption, drawbar power and specific fuel and minimum percentage of overall energy efficiency of tractor was in 100% fuel. Drawbar power in fuel combinations did not change and specific energy consumption reduced up to 0/4 liter per kilowatt hour and overall energy efficiency increased up to 3% by increasing of liquid petroleum gas and gasoline. Among fuel combinations (d80) combination was the best with maximum drawbar (19/43 kilowatt), minimum specific fuel consumption (0/55 liter per kilowatt hour) and maximum overall energy (18%).

Key words: MF tractor, synthetic fuel, overall energy and fuel measurement systems

Introduction

The most important and usual fuel used in transportation and agriculture in many countries of the world is fossil fuel. In agriculture all the machineries especially tractor use diesel fuel and this fuel is the main generator of machineries' power in all areas. The best substitutions for diesel fuel are compressed natural gas, liquid petroleum gas and biogas. Based on the researches done by Maji et al (2008) natural gas in comparison with gasoline in each kilogram produces more power and each kilogram natural gas needs more air to burn. This in relation to the power of a gas burning motor is of importance and this fuel could be used instead of fossil fuels. Musjuki et al (2000) found that in early paces 1000 cycle per minute the proportion of fuel to air in diesel fuel is higher in comparison to compressed natural gas, but with increasing engine speed the proportion of fuel to air in diesel increases and in compressed natural gas, it remains stable. The studies done on dual fuel engines (natural gas and gasoline) from the beginning until now implies that brake power, diesel engine brake torque is generally higher than dual fuel engine because the heat value of gasoline and natural gas is different and stoichiometric in dual fuel in all engine speeds is lower than specific diesel (Moril et al, 2007). Maximum pressure increases by increasing burning gas. Pressure and combustor temperature charts in dual fuel engines have two maximum points, the first is due to a delay in the ignition of incendiary fuel and the second is caused by the release of liquid energy through gas combustion. Having two points of maximum pressure is of the characteristics of dual fuel combustion. CO and NOx contaminants in diesel motors is higher than in dual fuel motors. Increasing the engine speed or ballast causes an increase in the heat performance of dual fuel engines (Hountalas and Papagiannakis, 2000). Increasing incendiary fuel causes an increase in output torque, heat performance and maximum pressure and reduces combustion noise, therefore combustion noise in dual fuel engines is lower than diesel engines (Nwafor, 2000). Mastafi and Rain (2008) studied combustion emissions of diesel engines with natural gas and biogas engines. The results of their study showed that using biogas and without any change in the structure of the engine, the performance remains stable, but PM and NOx contaminants reduce in the same working condition (speed, ballast and incendiary fuel). Cho et al (2007) showed that the proportion of natural gas fuel, incendiary fuel amount (gasoline) and injection time play an important role in maximum temperature of combustor and therefore in combustion emission and formation as well as in engine performance. Jeyhooni et al (2003) could make a dual fuel engine out of a diesel engine with minimum changes, and the results showed that it is possible to run a diesel engine properly with 90% gas and 10% gasoline with minimum changes. Studies on the performance and environmental issues of diesel engine changed into a dual fuel engine revealed that contaminant problems of diesel engine and current costs are reduced. In this study, done on the oil change times of gasoline engine and dual fuel engine, the results showed that using synthetic fuel system reduces oil change times and increases longevity (Shakeri, 2001). Agarwal et al (2001) studied natural gas injection method directly and succeeded in making a system with two fuel injections inside each combustor which increased engine power. Aslam et al (2006) designed an engine that works on gasoline and natural gas separately and automatically. This engine yielded differently in different weather conditions. They also claimed that gas and gasoline combination is useful when the engine works with low speed. Regarding the advantages of natural gas according to existing resources, pollution reduction and economically many gasoline engines were changed into gas engines, until now there has not been done enough studies on the performance parameters of diesel engines changed into dual fuel or synthetic fuel. Therefore MF399 tractor was equipped with synthetic gasoline fuel and LPG. The purpose of this study is to assess and measure precisely the amount of fuel and also to study the performance parameters of tractor in synthetic fuel of gasoline and gas on the track.

Methods

This study was performed in mechanization and agricultural machinery department of natural resources and agriculture university of Ramin, Khozestan, located in 35 kilometers in the north east of Ahwaz. MF399 tractor, used in this study, was previously equipped with the data collection system in a way that all performance parameters of tractor implements including fuel consumption, drawbar power, engine speed, wheel slippage percentage, real forward speed were simultaneously measured and stored in a laptop (Kazemi et al, 2013). The study included three phases of equipment installation related to gas system on the tractor, gauging and achieving synthetic fuel percentages and measuring and assessing the amount of gasoline and LPG and measuring drawbar power, specific fuel and overall energy efficiency of tractor in the farm.

The equipment of MF399 tractor with synthetic fuel system of gasoline and liquid petroleum gas (LPG) in this study was done without any change in the engine structure of tractor with synthetic fuel system of gasoline and LPG. Figure (1) shows how synthetic fuel system is implemented on a tractor.

Figure 1 and 2 – how synthetic fuel system of gasoline and LPG is implemented on a MF399 tractor

1. Injection pipe in the combustor 2. Combustor 3. Safety valves and gas gauge in combustor 4. High-pressure gas transmission pipelines 5. Venting 6. Electric valve off gas 7. Regulator 8. Water transmission pipeline to regulator 9. Mechanical valve 10. Mixer

Gas tank is installed in front of tractor and is transferred into regulator by high pressure gas pipelines. A mechanical valve was installed along the pipeline to make it possible for the operator to choose the fuel. Regulator is responsible to reduce the gas pressure from 200 PSI to 20 PSI and its temperature reduces rapidly due to expanding gas. It causes ice layers to be made and for this reason from the return of radiator water of engine speed, a hose comes into the regulator to prevent ice layer. Then gas is transferred into intake manifold through specific air transmission hoses. A mixer is installed at intake manifold to combine air and gas, so that air and gas get combined before entering engine. For controlling synthetic fuel, a scaled valve is implemented in the way of gas intake to engine to make it possible for the operator to choose the percentage of synthetic fuel while working. The amount of fuel was measured by an instantaneous fuel system. Figure (3) is a technical and pictorial schematic of instantaneous fuel measuring system that shows the amount of gasoline fuel with the accuracy of 1cc.

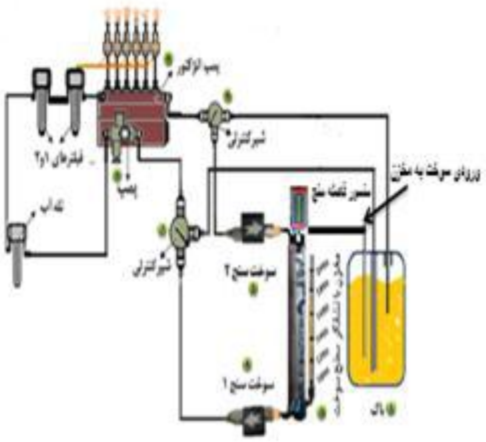

Figure 3 and 4. Schematic illustration of technical and fuel measurement system for the moment

Gauging and achieving synthetic fuels for performance assurance of tractor in the condition of using synthetic fuels of liquid gas and gasoline, workshop testing of tractor in different engine speeds and with a percentage of different synthetic fuels were done and at last synthetic fuels of 80% diesel and 20% liquid gas (D80), 60% diesel and 40% liquid gas (D60), 40% diesel and 60% liquid gas (D40), 20% diesel and 80% liquid gas (D80) and fuel control of 100% gasoline (D100) were achieved. In engine speed of rpm 1800 and two speed of 3/5 and 7 kilometer per hour with three repetitions and in the form of factorial experiment, blocks were analyzed accidentally on the track and by using Excel 2007 and SAS 9.1. The amount of gas was measured by a gravimetric method and DG8 with the accuracy of 20 grams. Tractive force of tractor was assessed using load cell and real speed of tractor by fifth wheel. Figure (5) shows how load cell, fifth wheel and other tools are implemented on a tractor.

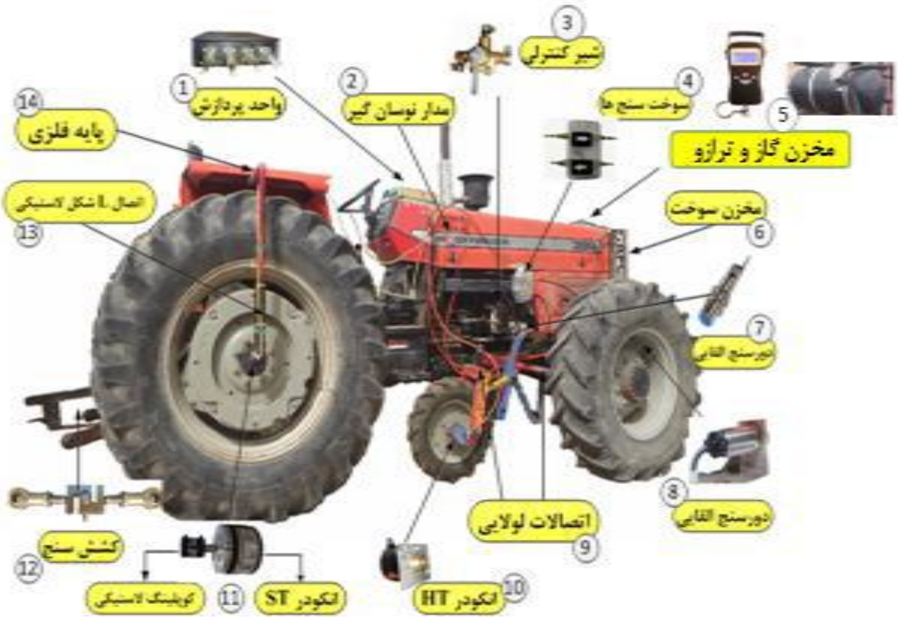

Figure 5. Massey Ferguson 399 tractor equipped with a combined fuel (diesel and liquefied petroleum gas)

1. Processing unit 2. Fluctuations gauge orbit 3. Control valve 4. Fuel gauge 5. Fuel tank of gas and fuel measurement scale 6. Fuel tank 7. Telemetry induction 8. Telemetry induction 9. Fittings 10. HT Encoder 11. ST Encoder 12. Tensiometer 13. Rubber connectors 14. Base metal

Measurement factors in this study included fuel measurement, drawbar power, specific fuel consumption and overall energy efficiency. Drawbar power was calculated by equation (1) in that Va is forward speed and F_{db} is tractive force and each of them and measured by fifth wheel and load cell and are sent to laptop through data collection system.

$$P_{db} = \frac{Va \times F_{db}}{3.6} \qquad (۱)$$

$$SFC = \frac{FC_{hr}}{P_{db}} \qquad (۲)$$

$$SFC = \frac{(FCd \times 10.2) + (FCl \times 12.4) \div 10.2}{P_{db}} \qquad (۳)$$

Specific fuel consumption (SFC) is specific fuel consumption index in terms of liter per kilowatt hour and is calculated by equation (2). In this equation, FC_{hr} is consumption fuel and P_{db} is drawbar power. But specific fuel consumption for synthetic fuel was calculated by equation (3). In this equation, FCd is gasoline fuel consumption, 10.2 is heat value of gasoline and is in terms of liter per kilowatt hour and FCl is liquid gas fuel consumption and 12.4 is its heat value and is in terms of kilogram per kilowatt hour (based on gasoline and liquid gas production of Iran in terms of kW-hr.1^{-1}).

$$OEE = \frac{P_{db} \times T}{(FCd \times 10.2) + (FCl \times 12.4)} \times ١٠٠ \qquad (۴)$$

Overall energy efficiency (OEE) in terms of this equation, P_{db} is the required drawbar power in terms of kilowatt, FCd is gasoline consumption in terms of liter per hour and FCl is liquid gas consumption, 10/2 and 12/4 are heat values of gasoline and liquid gas (based on Iran's production in terms of kW-hr.l^{-1}).

Results and Discussion

Table (1) indicates variance analysis, tractor performance parameters and the amount of fuel consumption in four different levels of synthetic fuel and one level of control fuel. The results of variance analysis shows that in gasoline and liquid gas petroleum there is statistically a meaningful difference among treatments of fuel combinations in level 1%. The amount of gasoline was not meaningful in proportion to speed, but the amount of liquid gas in proportion to speed was meaningful in level 5%. Fuel (gasoline and liquid gas) in mutual effect of fuel in speed was not meaningful. Drawbar power in fuel combinations did not have a meaningful difference, but in proportion to speed in level 1% became meaningful and mutual effect of fuel and speed on drawbar power did not have a meaningful difference. Specific fuel consumption and overall energy efficiency in proportion to the kind of fuel in level 5% and 1% became meaningful and in proportion to speed statistically there was no meaningful difference.

Table 1. Analysis of variance Parameters performance Massey Ferguson 399 with a combination of diesel fuel and gas (LPG)

		(MS)				
Total energy efficiency%	Specific fuel (Li/Kw.hr)	Drawbar power (KW)	Gas consumption (Kg/hr)	Gasoline consumption (Lit/ hr)	DF	SV
0.20	3.01	13.16	0.40	2.90	2	R
0.82**	6.50*	2.99^{ns}	20.66**	95.72**	4	Fuel
0.12^{ns}	0.46^{ns}	130.85**	0.72*	0.78^{ns}	1	Speed
0.23^{ns}	7.38*	6.35^{ns}	0.52^{ns}	0.42^{ns}	4	Fuel × Speed
16.51	10.73	17.62	9.1	11.56		CV

Table (2) shows the comparison of treatments' average of this study. In this study, the amount of gasoline consumption and liquid gas in different fuel combinations had meaningful difference. The amount of gasoline in different speeds was approximately the same, but liquid gas consumption in proportion to speed was different. Drawbar power was the same in all fuel combinations and there was no meaningful difference among different fuel combinations that was in accordance with the observations of Piroozpanah et al (2004). In these combinations, the best specific fuel consumption was 80% gasoline and 20% liquid gas (D80) to 0/52% kilowatt hour and in this treatment there was the best overall energy efficiency. Using liquid gas petroleum instead of gasoline reduced the amount of specific fuel, this was because of reducing fuel consumption and keeping drawbar power that increased overall energy efficiency of tractor in fuel combinations and was different with other treatments. Specific fuel was not different in different speeds, but overall energy efficiency increased when speed increased.

Table 2. Comparison of, Parvmtrhay performance Massey Ferguson 399 diesel with synthetic fuel gas (LPG)

Total energy	Specific fuel (Li/Kw.hr)	Drawbar power (KW)	Gas consumption (Kg/hr)	Gasoline consumptio(Lit/hr)	sort	Resources
18^{b}	0.55^{a}	19.43^{a}	0^{e}	11.18^{a}	D100	
20^{a}	0.52^{a}	19.18^{a}	2.39^{b}	9.72^{b}	D80	
18^{b}	0.54^{a}	$17.55a^{b}$	3.51^{c}	8.05^{c}	D60	Fuel
18^{b}	0.54^{a}	$17.85a^{b}$	4.47^{b}	5.83^{b}	D40	
18^{b}	0.54^{a}	16.98^{ab}	5.4^{a}	3.2^{e}	D20	
16^{b}	0.41^{a}	10.46^{b}	3.8^{b}	6.8^{a}	3.5 Km/hr	Fuel
20^{a}	0.50^{a}	20.88a	4.9^{a}	6.5^{a}	7 Km/hr	

Chart (1) shows consumed gasoline that maximum amount of consumed gasoline in fuel of 100% diesel was 12/8 liter per hour gasoline. Consumed fuel was under the effect of different fuel combinations. The injector reduces the amount of diesel fuel by increasing the amount of liquid gas intake into the engine after some seconds and instead of that, there is liquid gas providing engine power and shows the appropriate combination of liquid gas petroleum and gasoline for providing engine power. Chart (2) shows the amount of consumed gas substituted for gasoline in different combinations and speeds.

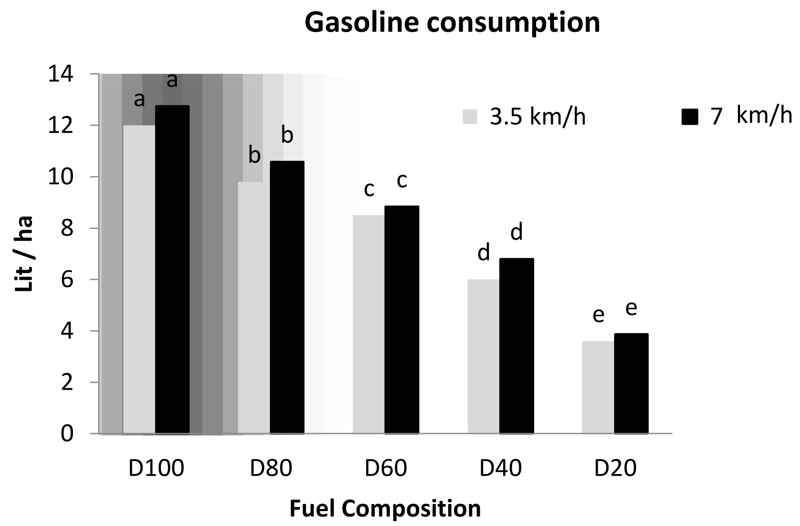

Chart 1. The amount of used Massey Ferguson 399 diesel with a hybrid fuel system diesel and gas (LPG)

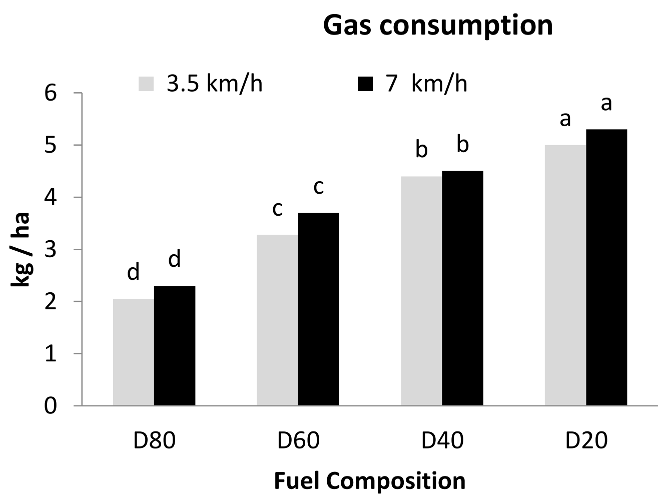

Chart 2. The amount of natural gas MF399 tractor equipped with a combination of diesel fuel and gas (LPG)

Drawbar power among different combinations of fuel and control fuel was the same and was not affected by fuel combinations and showed that the amount of liquid gas substituted for gasoline can keep the drawbar power of tractor. Drawbar power increased by speed increase and this amount of power increase in specific fuel was more than other fuel combinations. Chart (3) drawbar power in different speeds. It seems that to be due to the equivalence of liquid gas petroleum and gasoline which is in accordance with the findings of Piroozpanah et al (2004) and Qi et al (2007).

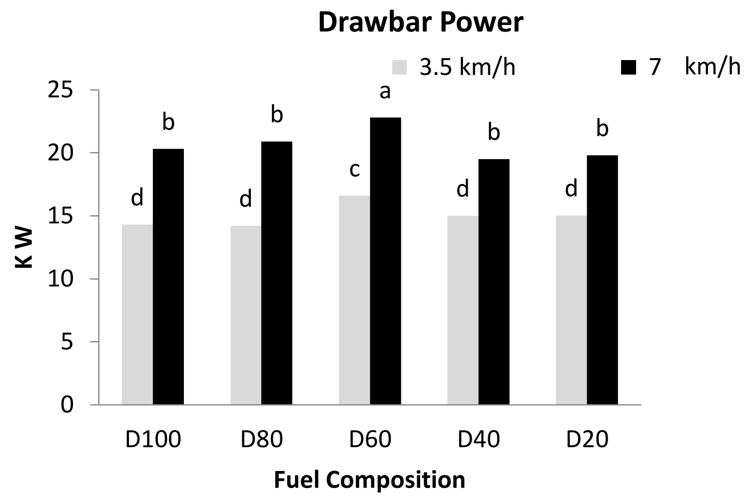

Chart (3). Massey Ferguson 399 tractor drawbar can be equipped with a combination of diesel fuel and gas (LPG)

Chart (4) shows specific fuel consumption of tractor. In this study, the maximum amount of specific fuel of tractor related to control fuel was in 7 kilometer speed and the minimum amount of specific fuel was in fuel combinations (D80) in 5/3 and 7 kilometer speeds. Experiments in this study showed that specific fuel decreases by increasing fuel combination and minimum specific fuel consumption was observed in 80% diesel and 20% gas and by increasing the proportion of gas combination, specific fuel consumption increases again, which is in accordance with findings of Leta et al (2012). Increasing speed also reduces specific fuel consumption, which is due to a direct relationship between speed and drawbar. By increasing speed, drawbar power increases, but consumed fuel was not effected so much and in general the amount of increased drawbar power was more than consumed fuel which in turn reduced specific fuel consumption.

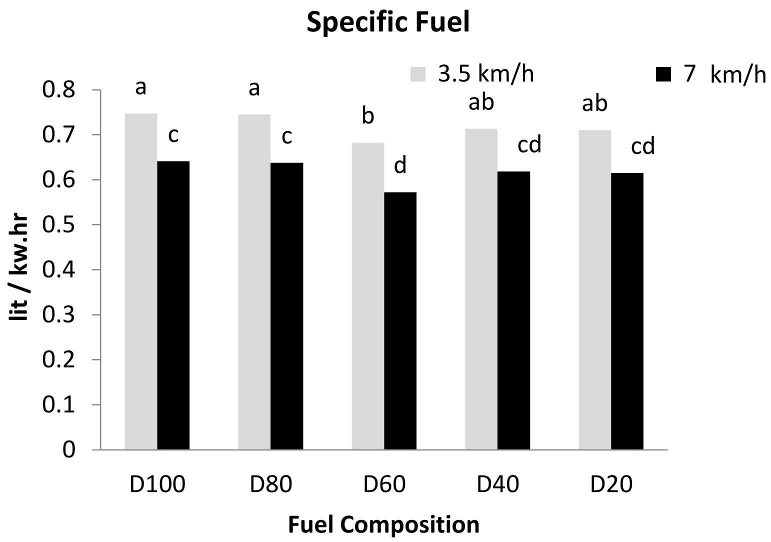

Chart (4). MF399 tractor equipped with a special fuel mixture of diesel fuel and gas (LPG)

Chart (5) shows overall energy efficiency of tractor at two speeds of 3.5 and 7 kilometer. Maximum overall energy efficiency in fuel combination (D80) in speeds of 3.5 and 7 kilometer was 23% and 16% overall energy efficiency, respectively. Overall energy efficiency began to decline by increasing gasoline and liquid gas more than 80%. Drawbar power increases by increasing speed, that causes an increase in the proportion of output (drawbar power) to input (overall fuel consumption of gasoline and liquid gas) and increases overall energy efficiency of tractor.

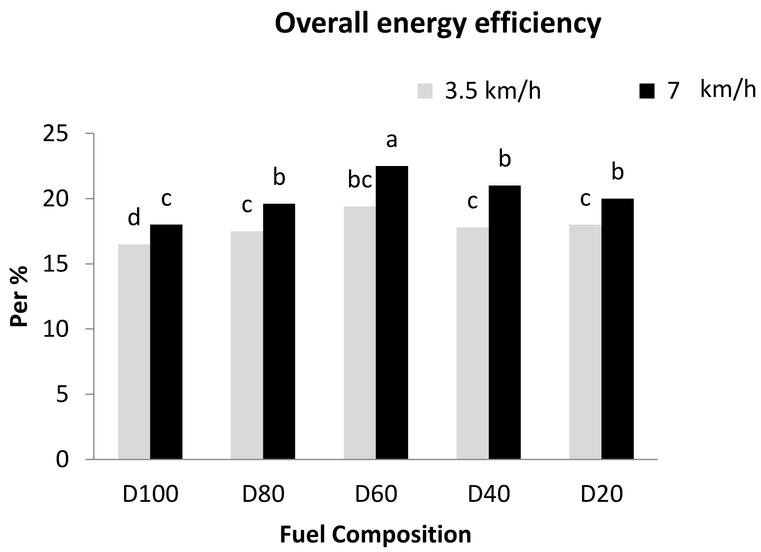

Chart (5) Overall energy MF399 tractor equipped with a combination of diesel fuel and gas (LPG)

Conclusion

In this study MF399 tractor was equipped with synthetic fuel of gasoline and LPG. The amount of gasoline was measured by using ultrasound sensors and graduated cylinder. The amount of consumed gas was measured by a gravimetric method using a scale. Forward speed and tractive force were measured by using fifth wheel and load cell and since a data collection system was implemented on the tractor, all data regarding drawbar power, specific fuel and overall energy efficiency were sent to laptop. Consumed fuel was different in different combinations and the fuel percentage of liquid gas increased by increasing the amount of LPG and this increase reduced the amount of gasoline and regarding that it keeps drawbar power, it is an appropriate replacement in different combinations for gasoline. There was no meaningful increase in the amount of gasoline and LPG by increasing speed, but this amount was different statistically in different fuel combinations. Specific fuel reduced 0.3 liter per kilowatt hour in different combinations by increasing liquid gas combination to gasoline that shows overall energy efficiency increases by fuel combination. This amount was 2% of overall energy efficiency of tractor.

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