TEKA Kom. Mot. Energ. Roln. – OL PAN, 2008, 8, 107–113

USABILITY ANALYSIS OF STATIC LOAD CYCLES FOR ASSESSMENT OF TRACTOR ENGINE OPERATION ECONOMY

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Summary. The paper presents results of tests on the AD3.152UR engine, carried out on a chassis dynamometer. The tests were made according to two different static load cycles, (5 and 8 phase). The operation economy of the tested engine was compared based on weighted averages of specific fuel consumption. It was found that in a 5-phase cycle the tested engine was characterized by lower specific fuel consumption and lower effective power, compared to an 8-phase cycle. It was also found that a 5-phase cycle could be representative for the province of Pomorze Zachodnie, provided the phase sequences are similar to the tractor engine time density characteristics.

Key words: agricultural tractor, combustion engine, static load cycle, operation economy.

INTRODUCTION

Numerous agricultural procedures are carried out with the use of a tractor of power, principally exceeding the power required for the cooperating machinery. Failure to select appropriate power causes the situation that numerous operations are made with the use of more energy than required. In addition to energy losses resulting from tractor weight growth, the losses related to the drop of general efficiency of an engine working on incomplete loads, thus causing the growth of the specific fuel consumption also play a significant role.

Engine operation optimization, in addition to the adjustment of parameters directly related to combustion and charge exchange process, consists in engine operation with a possibly high general efficiency. This condition can be achieved through appropriate selection of transmission in the vehicle drive system. Therefore, it is convenient to achieve a sufficiently high torque within the same power range, with a sufficiently low engine crankshaft speed [Grisso, Pitman 2001; Jahns, Forster 1990].

The available references provide information on the methods of evaluation and comparison of motor-vehicle engine operation economy. The fuel consumption index per 100 km is very useful and reliable here [Wisłocki 1989]. In case of agricultural tractors, however, the index cannot be fully impartial, because it does not consider the use of tractor in fieldwork or as a stationary drive source.

The valuation and improvement of engine operation economy indexes should be based on the time density characteristics in the actual application of the engine as it is done in e.g. motor-vehicle tests, according to the speed profile assumed in the test [Cichy 1986; Wisłocki 1989; Romaniszyn 2004]. No such tests exist in the field of tractor operation. The few attempts carried out in this area simply indicate the fact of incomplete use of the tractor engine power in farms indicating the possibility of improving the operation economy through a selection of the optimum transmissions. [Saglam, Akdemir 2002].

Some testing procedures contained in the exhaust emission measurement standards provide certain standardization in this area. According to the standard applicable in Europe the measurement of average exhaust emissions and engine operation economy are carried out based on fixed static load cycles, depending on vehicle group specification, while the load cycles constitute a combination of torque and engine crankshaft speed settings [PN-EN ISO 8178-4]. According to the tests, classification of agricultural tractors within motor-vehicles results in large convergencies and does not comply with the operating measurement results [Hansson et al. 1999; Hansson et al. 2001].

TESTING METHODOLOGY

A 5-phase research test was developed at the Department of Basics of Technology to reflect the tractor engine loads and it is, in the author's opinion, more representative for agricultural tractors than the load cycle according to PN-EN ISO 8178-4. The five phases (Fig. 1) include loads occurring during the work done by an agricultural tractor, characteristic for the province of Pomorze Zachodnie [Koniuszy, Dobrzycki 2006].

Table 1. Annual tractor engine load profile

Agrotechnical procedure (machine)	Power demand Ne [kW]	Relative procedure duration share, t [%]
Skimming (U 043/1)	31,50	6,07
	23,20	5,80
Plough (U 024)	45,00	4,53
	33,80	3,62
	25,50	4,71
	28,20	4,35
Soil preparation (U 708/2)	27,70	2,27
	21,40	2,99
	43,80	3,63
	28,20	1,45
Sowing and planting (S 045/2, S 211/1)	22,00	4,80
	28,70	1,36
	24,00	3,62
	17,70	3,62
	14,40	2,99
	44,20	7,25
Fertilizing (N 218/2)	29,50	5,53
	34,90	9,52
	48,70	1,08
	16,50	2,96
Crop harvesting (Z 643)	24,80	14,50
Transport (PS 2-09.07)	24,70	3,35
	Total	100

The data necessary to create a cycle were obtained from the farmsteads assessment questionnaires. The information collected concerned most of all: the location and area covered by each farmstead, production profile, crop structure, type of soil, tractor and machinery fleet. The surveys included the area representing ca. 0,5% of the farmland of Pomorze Zachodnie. The surveys were carried out in farms of various size, from 6 to 620 hectares and of various production profile. Upon statistical analyses consisting in determination of average values and carrying out probability distribution of the analyzed factors, such as: crop area, type of soils, quantity and type of tractors and machines, etc. the characteristics of an average (statistically average) farmstead in Pomorze Zachodnie were worked out [Koniuszy 2005]. A further analysis of data necessary to produce a substitute engine load cycle consisted in definition of particular crops and procedures done by the tractor, taking into consideration the accompanying machines, most frequently used in the surveyed farmsteads surveyed. Next, according to the general power balance of the tractor, the values of the particular balance items were determined, considering such parameters as: type of subsoil, width, depth and operating speed of the tool, etc. [Kuczewski 1974; Dajniak 1985]. In this way the demand for efficient power was calculated for each agricultural machine working with the tractor (Table 1) [Dobrzycki, Koniuszy 2005].

Using the methods of tractor engine operation optimization developed earlier [Wang, Zoerb 1989; Souza, Santa Catarina 1999] the transmissions for each agrotechnical procedure from Table 1 was selected and optimum engine speeds and torques loading the tractor's engine were determined [Koniuszy 2006]. Basing on this the load cycle of the tractor, the tested characteristic for an average farmstead in Pomorze Zachodnie was determined (Fig. 1).

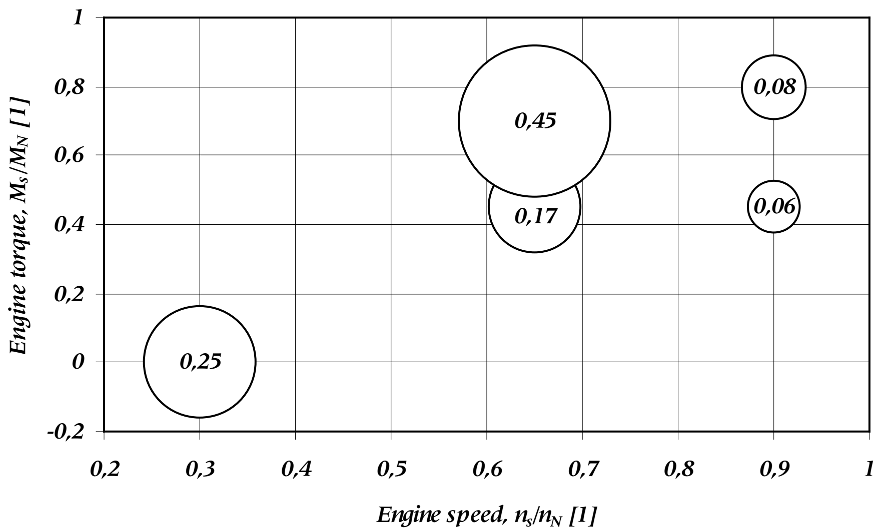

Fig. 1. Five-phase load cycle of the examined engine
(circle areas proportional to particular phase share)

Another comparable cycle was the 8-phase load cycle (C1), used in testing tractor engines, according to the applicable standard (Fig. 2) [PN-EN ISO 8178-4].

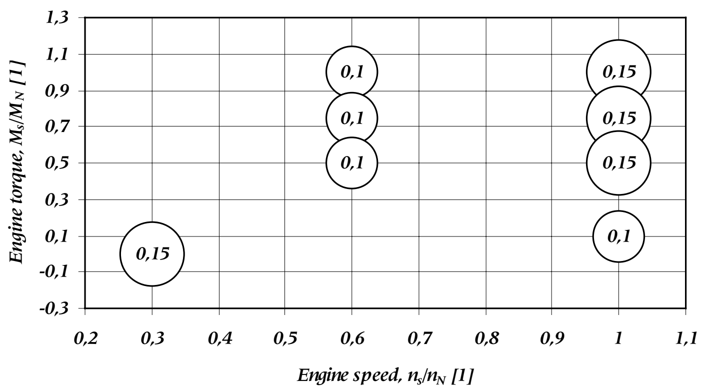

Fig. 2. Eight-phase load cycle of the engine tested (circle areas proportional to particular phase share)

The tests were carried out at the Department of Basics of Technology at University of Agriculture in Szczecin on a chassis dyno fitted with Froude type water brake. The test object was the AD3.152UR engine with a displacement of 2502 cm^3 and rated power 35 kW. Each measurement was made in a sequence of subsequent, increasing phase numbers. The minimum engine operation time during a single phase of each cycle was at least 10 min.

RESULTS AND DISCUSSION

The measuring results of specific fuel consumption were presented in the form of 2-dimensional distributions (Fig. 3 and 4).

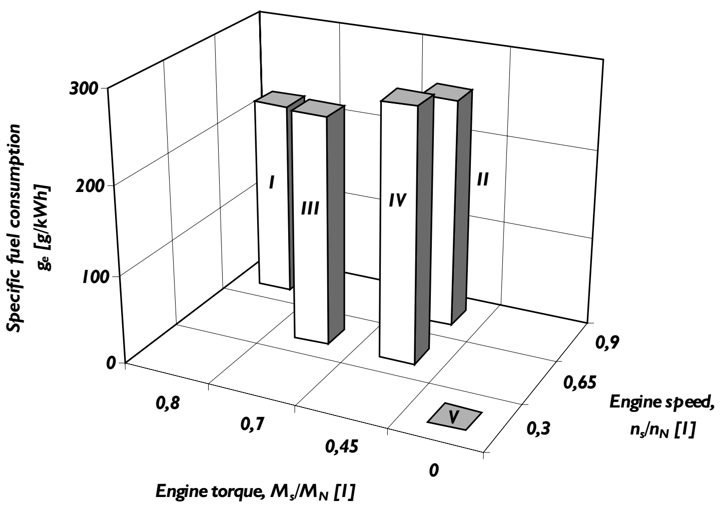

Fig. 3. Average values of specific fuel consumption in a 5-phase cycle

It was found that the highest specific fuel consumption, i.e. 426 g/kWh, was characteristic of the engine working in the 8-phase cycle (phase IV). The engine tested in the 5-phase cycle (phase I) reached the lowest specific fuel consumption, i.e. 220 g/kWh.

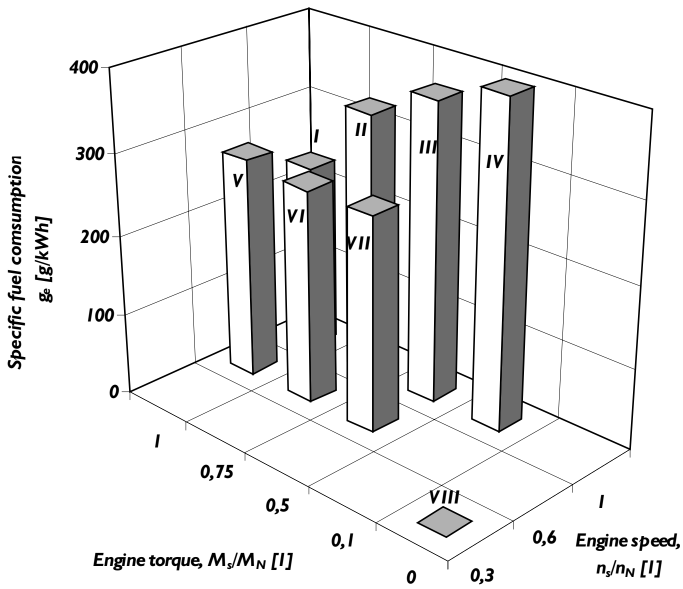

Fig. 4. Average values of specific fuel consumption in an 8-phase cycle

Phase IV of an 8-phase cycle was the least economic one in terms of specific fuel consumption. It corresponds to the engine loads characteristic of light tran-sport work and some procedures with participation of PTO (Power Take Off), when PTO rated engine power or possibly the highest tractor transporting driving speed is required. Phase I of the 5-phase cycle, however, corresponds to the load and crankshaft speed in terms of the highest general efficiency of the engine and thus is characterized with the highest operation economy.

Comparing the analysed testing cycles, each phase weight coefficient should be considered separately, because their share in the full cycle is different. Therefore, the comparison of weighted averages of specific fuel consumption the engine achieved in full cycles was by 15% higher compared to the 8-phase cycle. The 5-phase cycle was also characterized with the hourly average consumption by 83% lower and average exhaust smoke by 9% lower, compared to the 8-phase cycle (Table 2).

Table 2. Specification of average values of the AD3.152UR engine, considering weight coefficients

Type of cycle	Effective power, Ne [kW]	Fuel consumption per hour, Ge [kg/h]	Specific fuel consumption, ge [g/kWh]	Exhaust smokiness index, Kz [1]
5-phase	15,11	3,005	260	0,32
8-phase	21,04	5,452	305	0,35

One of the findings based on Table 2 is that the 5-phase load cycle to a lesser extent, i.e. just 43%, corresponded to the engine rated power compared to the 8-phase cycle in which the use of the engine rated power was 60%. Therefore, the agricultural tractors working in Pomorze Zachodnie are presumably characterized with better engine operation economy than it is suggested in the representative tests, according to the applicable standard. In order to prove this thesis, however, in addition to the theoretical load cycle, the tractor engine time density characteristics in operation of load sequences should be prepared, in order to confirm the similarity of the suggested load sequences.

CONCLUSIONS

1. The AD3.152UR engine working according to the 5-phase load cycle was characterized with operation economy expressed in specific fuel consumption, by 15% better than the 8-phase cycle.
2. The effective power weighted average of engine working in the 5-phase cycle was by 17% lower than in the 8-phase system.
3. It was proven that the 5-phase cycle reflects the load level of an agricultural engine in operation better than the 8-phase cycle.
4. The 5-phase load cycle may be representative of tractor engine tests provided that it is similar to the tractor engine time density characteristics.

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