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THE IMPROVEMENT OF TRACTOR ENGINE POWER USING THE DETERMINATION ALGORITHMS FOR THE OPTIMAL WORKING POINTS

Ilie DUMITRU, Dumitru BOLCU,
Mihnea CATANEANU, Claudiu OBOGEANU

UNIVERSITY OF CRAIOVA
FACULTY OF MECHANICS

ABSTRACT

Due to various working conditions and their permanent evolution, the characters of service of tractor engines are not always well determined.

The authors try to approach this subject with a view to obtain some algorithms based on the dependences between speed engine, effective torque, specific fuel consumption on one hand and speed engine, exhaust gases temperature and effective torque on the other hand.

KEY WORDS:
engine, optimal points, constant specific consumption, mathematic models.

1. INTRODUCTION

The using of the algorithms for the optimization of the engines that equip the classical working systems of the tractor – machine type is the first and most important step in creating the informational system of efficient management of these [1,2].

The phenomena that take place during the function of the engine at different conditions of functioning are complex and the mathematical models can be generally elaborated only on the basis of the experimental results. Such used procedures are called the system identification. According to this type of procedure, on the basis of the analysis of the experimental data of their processing, one can reach theoretical formulations, which are formed in the mathematical models that were looked for.

2. THEORETICAL PREMISES

Experimentally there were realized **h** determinations in which there was followed the specific fuel consumption $\mathbf{c_e}$ [g / kWh] at different values of the engine speed $\mathbf{n_e}$ [rot/min] and of the engine torque $\mathbf{M_e}$ [Nm]. There will be marked $\mathbf{c_{ek}}$, $\mathbf{M_{ek}}$, $\mathbf{n_{ek}}$ the values of the parameters at measuring k.

In order to elaborate a mathematical algorithm there must be determined interdependence among the variations of the specific fuel consumption c_{ek}, engine speed $\mathbf{n_e}$ [rot/min] and of the engine torque $\mathbf{M_e}$ [Nm].

In order to realize this, there will be considered the specific fuel consumption as being a moment and revolution polynomial function (relation 1).

$$c = \sum_{i=0}^{p} \sum_{j=0}^{s} a_{ij} \cdot M^i \cdot n^j \quad (1)$$

Using the method of the smallest second powers and applying the stationary conditions, there will be determined the evolution of the specific fuel consumption c_{ek}, on the basis of the analysis of the evolution of the experimental data (figure 1), as a function of the second degree in M_{ek} engine torque and n_{ek} engine speed (relation 2)

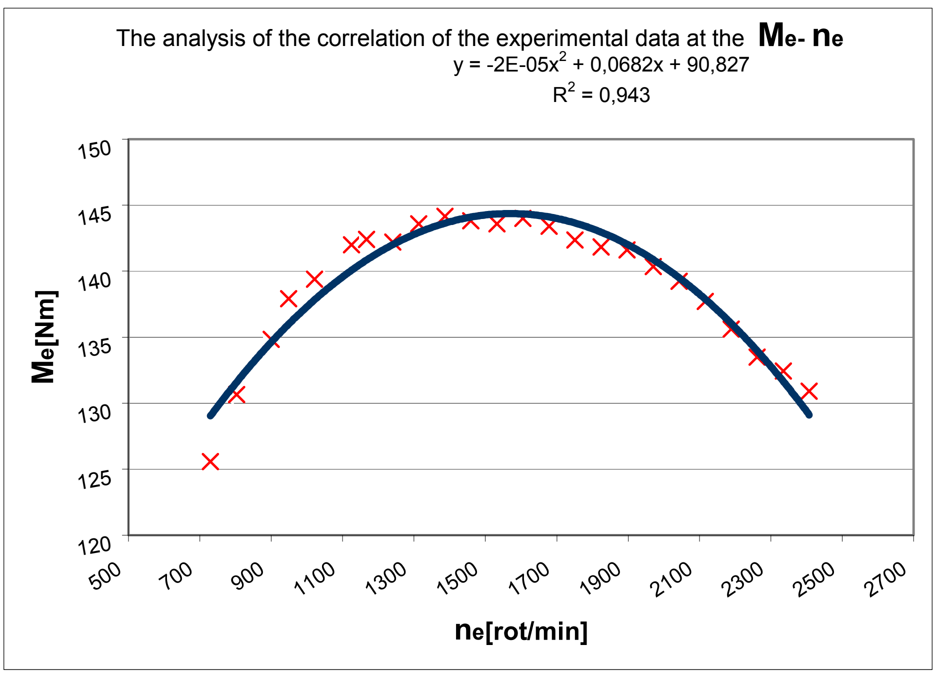

FIGURE 1. THE GRAPHIC EVOLUTION SPECIFIC TO THE CORRELATION OF THE EXPERIMENTAL OF THE ENGINE TORQUE – ENGINE SPEED

The system in the unknown $\mathbf{a_{ij}}$ is this case:

$$c = a_{00} + a_{10} \cdot M + a_{01} \cdot n + a_{11} \cdot M \cdot n + a_{20} \cdot M^2 + a_{02} \cdot n^2 \quad (2)$$

There will be considered as entrance data for this mathematical model, the values that have resulted at the processing of the data which were obtained at the raising of the engine speed characteristic (for example at the D 115 engine are presented in table 1)

$$f = \sum_{k=1}^{h} \left(a_{00} + a_{10} \cdot M_k + a_{01} \cdot n_k + a_{11} \cdot M_k \cdot n_k + a_{20} \cdot M_k^2 + a_{02} \cdot n_k^2 - c_k \right)^2 \qquad (3)$$

TABLE 1.
THE RESULTS OF THE PROCESSING OF THE EXPERIMENTAL DATA

Σ(ne)	ΣMec)	Σ(cec)	ΣM2)	Σn2)
40128	3460.9654	6340.2691	480040.353	71330365.4
ΣMn)	ΣM3)	ΣMn2)	ΣM2n)	ΣMc)
5537391.87	66702049.6	9782760767	765623690	877187.754
Σ(n3	Σnc)	ΣM4)	ΣM2n2)	ΣM3n)
1.36709E+11	10237209.6	9284112907	1.34452E+12	1.06056E+11
ΣM2c)	Σn4)	Σ(Mn3)	Σn2c)	ΣMnc)
121593367	2.76362E+14	1.8614E+13	18300229248	1411573098

3. THE MATHEMATICAL MODELATION FOR DETERMINING THE POINTS OF THE OPTIMAL FUNCTION OF THE ENGINE

In concordance with the above presented there can be formulated the following relation:

$$\left(\frac{\partial M}{\partial n} \right)_{P=ct} = \left(\frac{\partial M}{\partial n} \right)_{c=ct} \qquad (4)$$

Having the expression (1) of the specific consumption, the partial derivate of this in accordance with the engine speed has the form:

$$\left(\frac{\partial c}{\partial n} \right) = \sum_{i=0}^{p} \sum_{j=0}^{s} a_{ij} \left(i \cdot M^{i-1} \frac{\partial M}{\partial n} \cdot n^j + M^i \cdot j \cdot n^{j-1} \right) \qquad (5)$$

By derivating the relation (5) in accordance to the engine speed n at constant power there will be obtained:

$$\frac{\partial P}{\partial n} = ct \left(\frac{\partial M}{\partial n} \cdot n + M \right) = 0 \;\Rightarrow\; \frac{\partial M}{\partial n} = -\frac{M}{n} \qquad (6)$$

For determining the optimal functioning curve (for example at the D 115 engine), it considered that this is the geometric place of the defined optimum points (resulted from the condition that the M-n curve slopes at constant power and constant specific consumption to be "equal slope" theorem) [3,4].

The will replaced $\frac{\partial M}{\partial n}$ given by the relation (6) in relation (5) in order to determine the optimal functioning curve. For the considered function of second degree we have:

$$\frac{\partial C}{\partial n} = a_{10} \cdot \frac{\partial M}{\partial n} + a_{01} + a_{20} \cdot 2 \cdot M \cdot \frac{\partial M}{\partial n} + 2 \cdot a_{02} \cdot n + a_{11} \cdot \frac{\partial M}{\partial n} \cdot n + a_{11} \cdot M = 0 \quad (7)$$

Using relation (4) and grouping the terms we shall obtain the "optimum of the economic functioning curve of the engine" defined by the following function:

$$2a_{20} \cdot M^2 + a_{10} \cdot M - 2a_{02} \cdot n^2 - a_{01} \cdot n = 0 \quad (8)$$

There will be replace in (8) the determined coefficients by processing the data:

a[10]=-1.9785853,

a[01]=-0.1012663,a[20]=0.0059171128,a[02]=0.0000179

This, there will by obtained the curve that characterizes the optimal functioning of the D 115 engine (the correspondence engine torque – engine speed for a minimal specific consumption in any point of the engine speed characteristic).

0.0118343*M^2-1.9785853*M-
0.000035902856*n^2+0.1012663*n (9)

Using the soft MAPLE (version WMAPLE32) there will be realized the graphic representation of the specific curve of the optimal functioning of the engine (figure 2).

Implicitplot
({0.0118343*M^2 - 1.9785853*M - 0.000035902856*n^2 + 0.1012663*n}, n=600..2650,M=0..160);

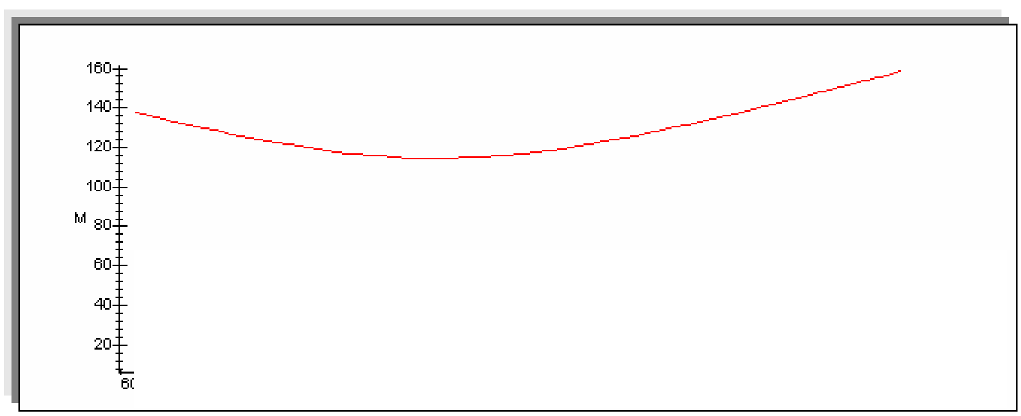

FIGURE 2. THE CURVE OF THE OPTIMAL FUNCTIONING FOR THE D 115

The rendering evident the optimum points and implicitly the optimum curve will be realized by studying the graphic evolution of this curve in the topogram of the constant consume curves (figure 3)

Implicitplot ({245.5=245+((n-1532-0.034*(M-115.2))/300)^2+((M-115.2+0.034*(n-1532))/13)^2,245.7=245+((n-1532-0.034*(M-115.2))/300)^2+((M-116.2+0.034*(n-1532))/13)^2,246=245+((n-1532-0.034*(M-115.2))/300)^2+((M-115.2+0.034*(n-1532))/13)^2,246.5=245+((n-1532-0.034*(M-116.2))/300)^2+((M-114.2+0.034*(n-1532))/13)^2,247=245+((n-1532-0.034*(M-115.2))/300)^2+((M-115.2+0.034*

(n-1532))/13)^2,246=245+((n-1532-0.034*(M-115.2))/300)^2+((M-115.2+0.034*
(n-1532))/13)^2,250=245+((n-1532-0.034*(M-115.2))/300)^2+((M-115.2+0.034*
(n-1532))/13)^2,254=245+((n-1532-0.034*(M-115.2))/300)^2+((M-115.2+0.034*
(n-1532))/13)^2,255=245+((n-1532-0.034*(M-115.2))/300)^2+((M-115.2+0.034*
(n-1532))/13)^2,260=245+((n-1532-0.034*(M-115.2))/300)^2+((M-115.2+0.034*
(n-1532))/13)^2,265=245+((n-1532-0.034*(M-115.2))/300)^2+((M-115.2+0.034*
(n-1532))/13)^2,0.0118343*M^2-1.9785853*M-0.000035902856*n^2+0.1012663*n},
n=1150..2650,M=38..160);

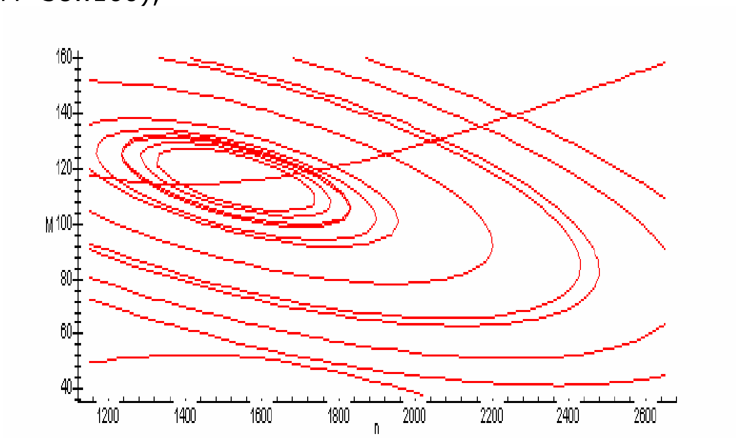

FIGURE 3. THE GRAPHIC EVOLUTION OF THE OPTIMUM FUNCTIONING, REFERRING TO THE TOPOGRAMA OF THE CONSTANT CONSUMPTION CURVES

4. Conclusions

- the proposed method allows finding, on the basis of the experimental data of the optimum functioning points of a engine with compression ignition;
- in accordance to the above presented the optimum curve (the geometric place of the optimum functioning points) is defined as a couple function for witch the fuel consumption is minimal for every level of constant power;
- the analytic expression which was found allows, using the instruments offered by the computational engineering, the projection of some routines necessary for making an informational system for the board whose attributes are the engine monitoring and the offering recommendations regarding an optimal functioning.

REFERENCES

1. Dumitru, I., ş.a., Techniques of assisted projection for the optimization of some sequences of projection in the road vehicles domain, Analele Universităţii din Craiova- Seria Mecanică, Craiova, 2002;
2. Dumitru,I., Popescu S., Optimizarea parametrilor specifici ai sistemelor tip tractor-maşină de lucru prin utilizarea sistemelor informaţionale, INMATEH 2004, ISSN 1583-1019, Bucuresti, 2004;
3. Harris, H.D., and F. Pearce, A universal mathematical model of diesel engine performance , jaer 47(1), 1990;
4. Kipp, Johan-Carsten, Optimierung, des Leistungsumsatzes von Traktoren durch den Einsatz electronischer Hilfsmittel, Fortschr.-Ber. VDI Reihe 14, Nr. 35, Düsseldorf, VDI-Verlag, 1987.