R.V. Kuz

MOVING VEHICLE PARAMETERS MONITORING SYSTEM

R.V. Kuz
(Institute of Thermoelectricity, 1, Nauky Str., Chernivtsi, 58029, Ukraine)

• *A recording system is developed for an automatic collection of information on the parameters of a moving vehicle, as well as of a thermoelectric generator installed on it. Collected information allows optimal design of a thermoelectric generator using vehicle exhaust heat for given class of vehicles and driving mode. The system was tested on a Volkswagen Transporter equipped with a diesel engine.*

Introduction

The use of waste heat from the internal combustion engines is a relevant applied problem of thermoelectricity. World producers of vehicles, as well as companies of thermoelectric profile, give much prominence to the development of efficient thermoelectric generators for vehicles. The purpose of such works is to increase fuel saving to 10% due to the use of engine exhaust heat for electric energy generation.

The largest companies making it their mission to create industrial prototypes of generators and their large-scale production are companies Hi-Z [1], BSST [2] and General Motors [3] in the USA. In Japan, the problems of creating automotive generators are most widely addressed by companies Komatsu [4], Nissan [5] and Shiroki [6]. In Germany, company Volkswagen and company BMW together with DLR (German Airspace Centre) represented their developments of thermoelectric automotive generators [7]. In Ukraine, the problems of creating efficient thermoelectric generators for the internal combustion engines are solved at the Institute of Thermoelectricity. A theory and computer design methods for such generators have been developed [8-12] with regard to peculiarities of dynamic operating modes of engine in real driving.

A prerequisite for calculations and design of optimal generator construction is the availability of a detailed information on exhaust gas parameters (temperature, velocity, thermal power) as a function of driving mode (vehicle speed, engine revolutions, tilt angle, wind velocity, etc).

The purpose of the work is to create an automatic system of monitoring the basic vehicle parameters describing vehicle motion state, as well as parameters of thermoelectric generator installed on the vehicle.

1. Description of monitoring system

1.1. The intended use of monitoring system

The system is intended for automatic recording of moving vehicle parameters and storing sensor readings into an embedded memory with a possibility of their further computer processing by means of specially developed software.

Monitoring system collects and records the following data:

- exhaust gas temperature at three points of vehicle exhaust system;
- ambient temperature;
- gas flow velocity in exhaust pipe;
- vehicle speed;
- wind velocity relative to driving direction;

– vehicle-tilt angle relative to horizontal axis;
– engine revolutions;
– vehicle coordinates with attachment to real terrain map;
– electric current, voltage and power of thermoelectric generator.

In operation, current data from the sensors are reflected on a built-in display screen of recording device. Based on the processed data, the tabulated and graphical time dependences of moving vehicle parameters are obtained.

1.2. Basic units of monitoring system

A monitoring system consists of data collection sensors, a 16-channel analog-to-digital converter, a stand-alone microcontroller recorder with digital information conversion software and a GPS-navigator. Schematic diagram of monitoring system is shown in Fig. 1. Analog signals from all the sensors are processed by analog-to-digital converter and stored in recording device memory. A stand-alone desk allows control over the process of recording and display of recorded information. The system has a USB-interface for the exchange and processing of information stored in computer.

Exhaust gas temperature and ambient temperature is recorded by measuring thermocouples of the type “chromel-alumel” that have a linear dependence of EMF over a wide temperature range. The error of temperature measurement is not more than 2%.

The cold side temperature of thermocouples is recorded by resistance thermometer (TC-0295) in the range of –20 to +40ºC with the error not more than 1%.

Vehicle speed is measured by vehicle induction wheel speed sensor, as well as by a GPS-navigator (here we used a GPS-logger G-log 760).

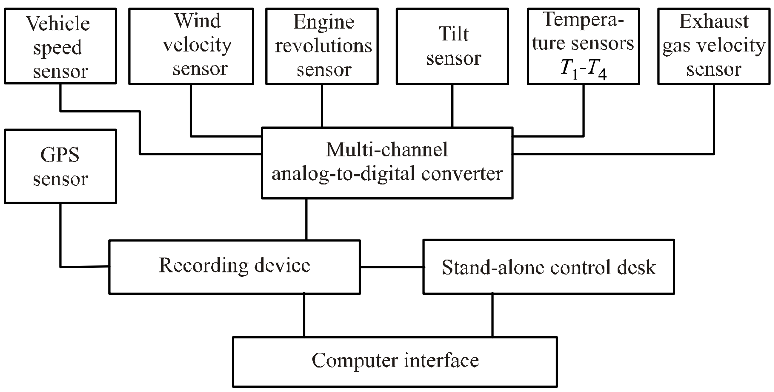

Fig. 1. Schematic diagram of monitoring system.

Engine revolutions are measured by parallel connection of a system to vehicle revolutions sensor. The system works both with the induction-type sensors and the Hall sensors.

Wind velocity relative driving direction is measured by aviation Venturi tube TV-980U in the range of 2 to 50 m/s with the error not more than 3%.

Exhaust gas velocity is measured by the Pitot sensor DP-3310M in the range of 1 to 60 m/s with the error not more than 3%.

Vehicle-tilt angle is measured by electronic inclinometer GON-4312 in the range of ±25º with the error not more than 0.1º.

Vehicle geographical coordinates are obtained from the GPS-sensor to an accuracy of 10 m.

Sensor polling period can be set from 4 to 1 hour.

The system can be powered both autonomously with the possibility of trouble-free operation up to 8 hours and from car’s lighter socket. The embedded recorder memory can store up to 10000 entries.

2. Monitoring system test results

The elaborated system was installed and tested on a Volkswagen Transporter vehicle, equipped with a diesel engine of power 96 kW. Thermocouples for measuring the exhaust gas temperature were installed at 3 points of exhaust system: in front of a catalytic converter (catalyst), after the catalyst and immediately in front of an acoustic filter (muffler). A sensor of exhaust gas velocity was installed at the same place. A sensor of wind velocity was fixed on a remote rod on vehicle roof to avoid measurement distortion by air fluxes around the vehicle.

Examples of collected and computer processed data for city vehicle driving are given in the figures.

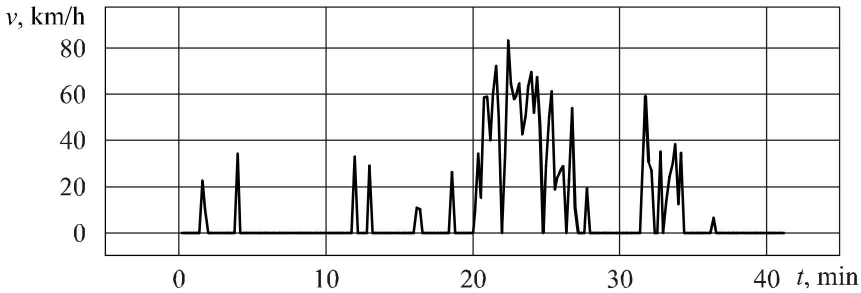

Fig. 2. Vehicle speed.

Fig. 2 represents a dependence of vehicle speed. Fig. 3 shows the respective dependences of exhaust gas temperature at different points of exhaust system.

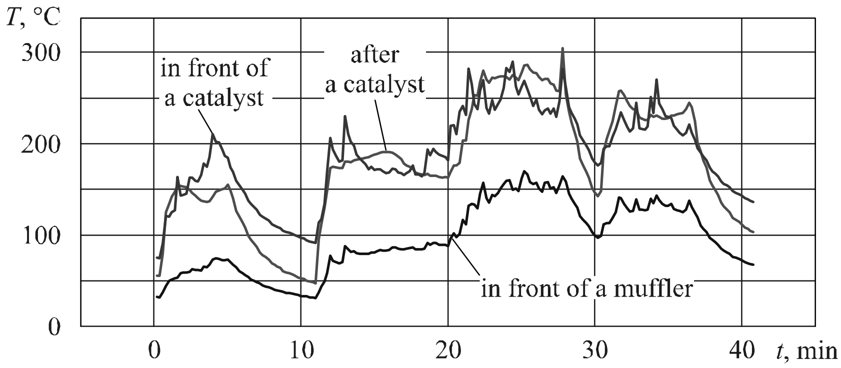

Fig. 3. Exhaust gas temperature.

Fig. 4 shows vehicle motion route in a city with attachment to satellite map and time.

Fig. 4. Vehicle motion route on satellite map.

3. Processing of results. TEG design

The elaborated system was used to obtain the data for a Volkswagen Transporter driving mode in a New European Driving Cycle (NEDC).

TEG design was done according to the procedure described in the previous works [12-13].

Figs. 5 and 6 show the exhaust gas energy parameters for vehicle driving mode in NEDC, as well as optimal module temperature calculated according to procedure [13].

Fig. 7 shows calculated electric power of TEG.

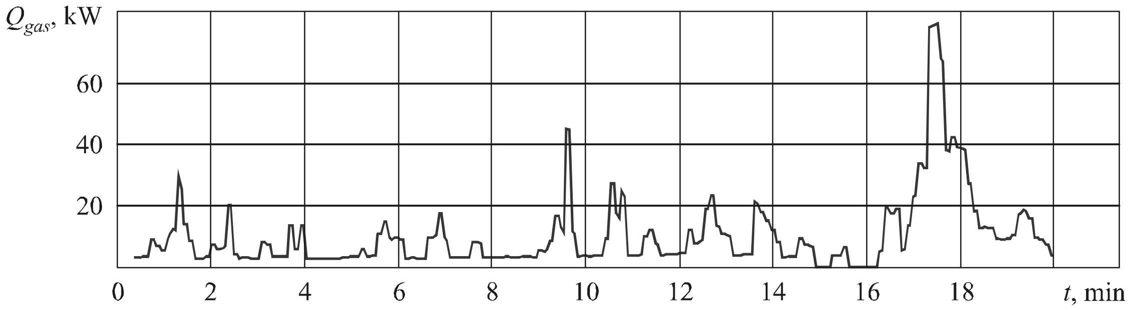

Fig. 5. Exhaust gas thermal power.

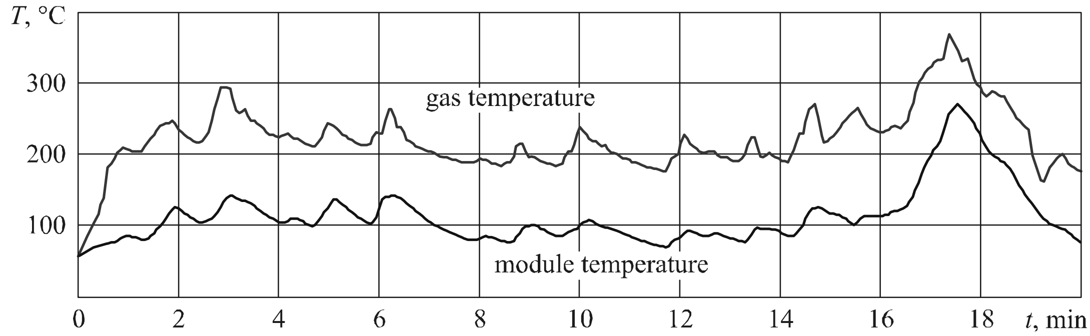

Fig. 6. Exhaust gas temperature and module temperature calculated according to procedure [13].

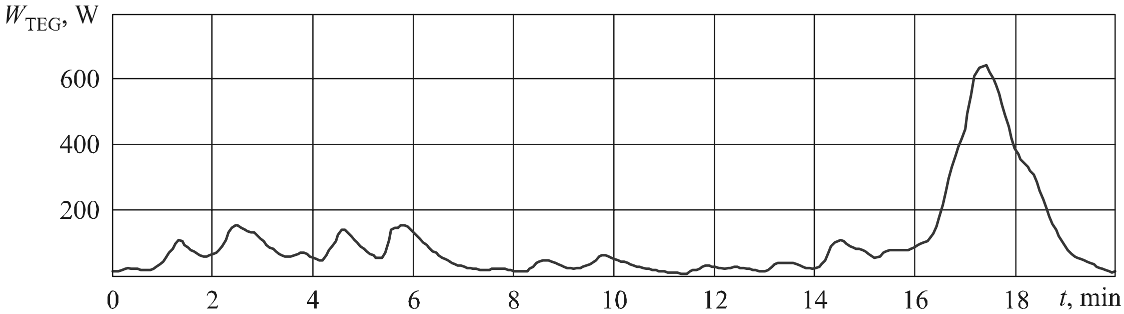

Fig. 7. Electric power of thermoelectric generator.

The average electric power of the designed generator is 110 W in a single NEDC. Maximum electric power (at a speed of 110 km/hour) is 615 W. The cold side temperature of modules is 50ºC.

The results obtained are in good agreement with the experimental data [8].

Conclusions

1. A system for monitoring parameters of moving vehicle is created which assures measuring in a dynamic mode the energy parameters of vehicle exhaust gas, as well as parameters describing vehicle motion state. The total error in measuring the exhaust gas thermal power is not more

than 9%. The error in measuring motion parameters is not more than 3%.

2. The results obtained serve the base for the optimal design of a thermoelectric generator operated on exhaust gas heat for a specific vehicle and driving mode.
3. The above example of calculating the generator of maximum power 615 W and average power 110 W (for NEDC) corresponds to the experimental results.

Acknowledgement. The Author is sincerely grateful to academician of NAS Ukraine L.I. Anatychuk for the formulation of an interesting and timely problem, the directions and support during the performance of the work. Big gratitude is due to V.A. Tyumentsev for having fulfilled the technical part of the work.

References

1. N. Elsner, J. Bass, S. Ghamaty, D. Krommenhoek, A. Kushch and D. Snowden, Diesel Truck Thermoelectric Generator, *Advanced Combustion Engine Technologies. – FY 2005 Progress Report*, p. 301 – 305.
2. D. Crane, L. Bell, Progress Towards Maximizing the Performance of a Thermoelectric Power Generator, *Proc. 25th International Conference on Thermoelectrics* (Vienna, Austria, 2006), p. 11 – 16.
3. Jihui Yang, F. Seker, R. Venkatasubramanian, G.S. Nolas, C. Uher and H. Wang, Developing Thermoelectric Technology for Automotive Waste Heat Recovery, *Advanced Combustion Engine Technologies. FY 2006 Progress Report*, p. 227 – 231.
4. T. Kajikawa, Current Status of Thermoelectric Generation Technology in Japan, *J.Thermoelectricity* **2**, 21 – 31 (2007).
5. K. Ikoma, M. Munekiyo, K. Furuya, M. Kobayashi, T. Izumi and K. Shinohara, Thermoelectric Module and Generator for Gasoline Engine Vehicles, *Proc. 17th International Conference on Thermoelectrics* (Nagoya, Japan, 1998), p.464 – 467.
6. E. Takanose, H. Tamakoshi, The Development of Thermoelectric Generator for Passenger Car, *Proc. 12th International Conference on Thermoelectrics* (Yokohama, Japan, 1993), p. 467–470.
7. “Thermoelektrik-Eine Chance Fur Die Atomobillindustrie”, Berlin, 2008.
8. L.I. Anatychuk, O.J. Luste and R.V. Kuz, Theoretical and Experimental Studies of Thermoelectric Generator for Vehicles, *J. Electronic Materials* **40**(5), (2011).
9. L.I. Anatychuk and R.V. Kuz, Computer Designing and Test Results of Automotive Thermoelectric Generator, *Thermoelectrics Goes Automotive* (Berlin: Expert Verlag, 2011).
10. L.I. Anatychuk, O.J. Luste, R.V. Kuz and M.N. Strutinsky, Inverse Problems of Thermoelectricity, *J. Electronic Materials* **40**(5), 2011.
11. L.I. Anatychuk and R.V. Kuz, Materials for Vehicular Thermoelectric Generators, *J.Electronic Materials* **41**(6), (2012).
12. L.I. Anatychuk, R.V. Kuz, Theory and Computer Simulation of Automotive Thermoelectric Generators, *ICT/ECT-2012* (July 9th-12th, 2012, Aalborg, Denmark).
13. L.I. Anatychuk, R.V. Kuz and Yu.Yu. Rozver, Thermoelectric Generator for a Petrol Engine, *J. Thermoelectricity* **2**, 97 – 104 (2012).

Submitted 09.11.2012.