ПЕРСПЕКТИВНЫЕ ДВИГАТЕЛИ ВНУТРЕННЕГО СГОРАНИЯ

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WAYS TO IMPROVE EFFECTIVENESS OF ICE AS POWER UNIT OF CAR HADI-34

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Abstract. *The results of searching for ways to reduce fuel consumption record car HADI-34 when using a power plant subcompact four-stroke engine are given. Concluded the feasibility of changing the external high-speed performance at throttle-free regulation.The preliminary calculations, showing the effectiveness of increasing modernization of the engine compression ratio and stroke were performed.*

Key words: *record automobile, fuel consumption, four-stroke engine, compression ratio, stroke, high-speed performance.*

ПУТИ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ ПРИМЕНЕНИЯ ДВС КАК СИЛОВОЙ УСТАНОВКИ АВТОМОБИЛЯ ХАДИ-34

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Аннотация. *Представлены результаты поиска путей снижения расхода топлива рекордным автомобилем ХАДИ-34 при использовании в качестве силовой установки малолитражного четырехтактного двигателя. Сделан вывод о целесообразности изменения внешней скоростной характеристики при бездроссельном регулировании. Выполнены предварительные расчеты, показывающие эффективность модернизации двигателя увеличением степени сжатия и хода поршня.*

Ключевые слова: *рекордный автомобиль, топливная экономичность, четырехтактный двигатель, степень сжатия, ход поршня, скоростная характеристика.*

ШЛЯХИ ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ ВИКОРИСТАННЯ ДВЗ ЯК СИЛОВОЇ УСТАНОВКИ АВТОМОБІЛЯ ХАДІ-34

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Анотація. *Представлено результати пошуку шляхів зниження витрати палива рекордним автомобілем ХАДІ-34 при використанні як силової установки малолітражного чотиритактного двигуна. Зроблено висновок про доцільність зміни зовнішньої швидкісної характеристики при бездросельному регулюванні. Виконано попередні розрахунки, які показують ефективність модернізації двигуна збільшенням ступеня стиснення і ходу поршня.*

Ключові слова: *рекордний автомобіль, паливна економічність, чотиритактний двигун, ступінь стиснення, хід поршня, швидкісна характеристика.*

Introduction

Every year the international competition for fuel economy Shell Eco-marathon [1] attracts more than 200 teams and 3,000 students-participants. In 2010, a team from Ukraine participated in this competition for the first time. The students of KhNAHU made HADI-34 racing car in the

Laboratory of Racing Cars (LRC) [2], which is worthy to compete with European teams, demonstrating the potential of the national school of motoring.

Participation of the Ukrainian team in the Shell Eco-marathon competition during a three year period using HADI-34 car allows setting fuel economy records of Ukraine. Unfortunately, the progress remains local, allowing excelling only on the territory of CIS. Therefore, the modernization of HADI-34 car remains actual. Analysis shows that the reserves for improving the performance of HADI-34 lie in reducing the vehicle weight, improving its aerodynamic properties, and using of advanced telemetry technologies. However, the most important condition to ensure the competitiveness of the car is to improve the technical and economic performance of the engine.

Analysis of publications

The participants' experience shows that the car should move in the modes of dispersal and reel under race conditions. At the same time it is possible to comply with the competition rules [3] in case of possible passage of the racing track with an average speed of 30 km/h. In order to reach the specified speed of the vehicle, weighing up to 100 kg including the pilot, does not require a powerful power train. The main task is to ensure the engine acceleration to the set speed within a minimum period of time that is about 10 seconds. For further analysis of engine operating conditions there should be specified two stages of successful racing track passage: the start and acceleration of the vehicle on the track in case of its maximum allowable speed decrease as a result of friction, changes of track profile, etc.

The leaders of competitions start the engine only twice per lap with the length of 1626 m. Since the purpose of the competition is to achieve maximum fuel economy, the competitors use the power units in their racing cars with maximum efficiency. The participants acting in the classification «Internal Combustion Engines with Positive Ignition» in the vast majority use four-stroke mini art engines.

The most popular among the participants (90–95 %) is a four-stroke 1CH3, 5/2, 6 engine (HONDA GX- 25) (fig. 1) [4].

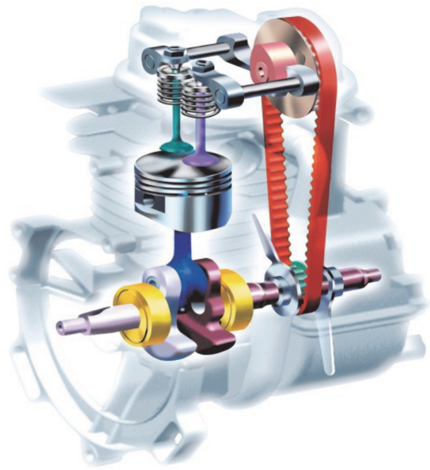

Fig. 1 HONDA GX-25 (35) Engine

The results obtained in the races revealed the maximum possible value when using such a serial engine (800 km per 1 liter of gasoline). Therefore, the teams are trying to make the engine as efficient as possible by its modernization. As indicators obtained by KhNAHU team do not reach the specified maximum possible value, then at the first stage of improving the power plant it is useful to consider the possible ways of improving the parameters of the HONDA GX-25 engine using at maximum the element base of the prototype engine.

Objective and Problem Statement

Based on the above stated, the purpose of this study is to identify the ways to reduce the fuel consumption of a four-stroke ignition engine HONDA GX-25 (35).

To achieve this goal it is necessary to solve the following problems:
1. Conduct the analysis of ways to improve the engine performance.
2. To offer the technique of engine modernization.

Analysis of ways to improve the engine performance

The conducted analysis shows that the participants which obtained record results use piston engines of self-developed design. The main difference between these engines is extremely high compression ratio (ε) and the ratio of the piston stroke/ bore diameter (*S*/*D*) which exceeds 2.

The best results obtained in terms of the competition are presented in table 1.

Table 1 Indicators of the teams-participants of the competition in the class «Piston ICE with Positive Ignition»

Team, country	Place, car	Year	Result, km/l	Engine	Basic parameters	
					S/D, mm	ε
HAHT, France [5]	1-st, Micro-joule	2013	2980	Original 4-stroke 30 $см^3$	n.i.	n.i.
GAMF, Hungary [6, 7]	2-nd, Megametre	2013	2696	Original 4-stroke	58/31,5	14/22
	2-nd	2012	2661		60/27	17
	8-th	2010	1588		45/31,5	n.i.
	–	–	600–800	HONDA GX-25 4-stroke	29/35	8
Remmi team, Finland [8]	3-rd, Remmi-7	2013	2694	4-stroke	70/27,7	16,8
	Remmi-6B	2002	2485	4-stroke	55/39	17,3
	Remmi-5E	1998	1689	4-stroke	43/35	15
PennStateUniversity, USA [9]	1- st, CT 2.0	2013	1529	Bridge&Stratton 4-stroke	47,7/65,1	n.i.
LRC, Ukraine [2]	23-rd, HADI-34	2011	575	HONDA GX-25 4-stroke	29/35	8

The increase of engine efficiency can be expected when the basic conditions are fulfilled:
– increase of compression rate;
– reduction of mechanical losses ;
– increasing of stroke for more complete combustion of the working fluid;
– increase of the filling ratio;
– improvement of ignition and fuel supply systems.

From the theory of engines it is well known [10] that the increase in efficiency of the Otto cycle is associated with an increase in the degree of compression and piston stroke.

Evaluation of the effectiveness of S and ε increase in the HONDA GX- 25 engine was carried out in the AVL BOOST environment (fig. 2 and 3). Selection of simulation environment is due to the further possibility of carrying out a computational study of the processes immediately occurring in the engine in AVL Cruise environment under competition conditions. For this purpose there was created a special model.

The measures involving the redesign of the engine is the increase of the piston stroke. Experience shows that the sufficient energy capacity for the car participating in the competition does not exceed 0,8 kW. Increase of S from 29 mm to 35 mm, while maintaining regular compression ratio, made possible the reduction of the crankshaft rotation rate for achieving the specified power from7000 min – 1 to 4650 min-1 (table 2), which also had a positive effect on the torque that increased by 22 %.

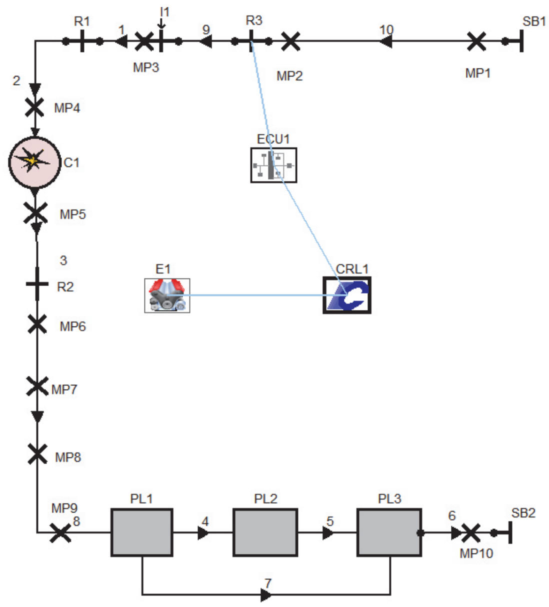

Fig. 2. Engine Design Circuit

Workflow calculations showed that an additional increase in the geometric compression ratio from the operational 8 to 11 units will reduce the fuel consumption by 11,5 % and increase the effective engine performance (power, torque). A further increase of ε to 17 units will further reduce the fuel consumption by 5 %. But at such a high degree of compression there occurs the problem of detonation. To combat this phenomenon, the teams, leaders of competitions, use increased energy ignition systems with the installation of two plugs at one cylinder. They also use detonation resistant fuels, such as ethanol.

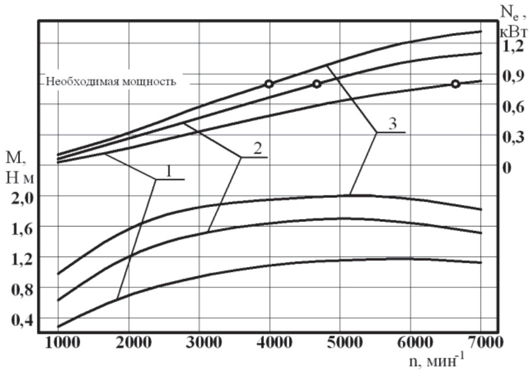

Fig. 3. Speed characteristics: 1 – operational engine S = 26 mm, ε = 8; 2 – S = 35 mm, ε = 8, 3 – S = 35 mm, ε = 11

Table 2 Indicators of engine modernization effectiveness

D, мм	S, мм	S/D	ε	Frequency at N_e=0,8 kW	g_e, g/(kW-hour)
35	26	0,74	8	6700	300
35	35	1	8	4650	251
35	35	1	11	4000	222

An important prerequisite, which allows considering the possibility of increasing the compression ratio to 17, is the limited time of engine operation. Consequently, in the over-piston space there are no prerequisites for the occurrence of detonation. It is known [11] that the temperature rise of surfaces bounding the combustion chamber is a rather inertial process with a characteristic time constant k = 0,022 s^{-1}. In this case for conditions of starting the engine with access to the nominal mode (start of the car within τ = 11 s), an increase in temperature of the piston bottom is $1 - e^{-k \cdot \tau} = 0{,}221$, or 22,1 % of the total temperature drop. The time constant k was obtained experimentally during the test of the SMD-60 engine during the start of the warmed-up engine reaching the nominal mode.

The obvious observation is that these changes do not limit the possible ways to reduce fuel consumption and create the necessary high-speed performance. Thus, the use of the injection system with electronic control is a choiceless way of providing of fuel supply. Installation of the injector is possible before the inlet valve that has been currently implemented in the HADI-34 motor car. In the long term the fuel must be injected directly into the cylinder.

Improving the quality of admission of the incoming charge with throttle-free regulation of the fuel ratio is associated with the modernization of the intake system, the introduction of dynamic boost and the reduction of inlet and outlet losses.

Automation of the engine start requires the use of appropriate launch systems. In this case the use of a special electric motor is the most effective means.

Methodology of Engine Modernization

For the implementation of the specified structural changes leveraging ICE serial parts there was created a parametric engine model in CAD/CAE environment of the Inventor system. Changing the design of the engine is to install a composite crankshaft on three supports-roller bearings, which are located in the sump, which is connected with the mono-block engine through a spacer with 9 mm thickness. It allows increasing the crank radius from 13,5 to 17,5 mm. These design changes can increase the compression ratio from 8 to 11 units. It should be noted that the additional support of the crankshaft is a prerequisite of equipping the engine with a starting system with an electric starter.

As noted above, the application of the HONDA GX-25 engine, even an upgraded one, will not allow achieving the leading positions in competitions. Therefore, in the future there is supposed to be created an original engine, adapted to the conditions of the competition.

Findings

Analysis of competitors, the tactics of lapping the distance and design parameters of vehicles engines of winner teams is carried out.

The conditions of engine operation consisting in the start-up in the throttle-free mode that allows reaching the power of about 0,8 kW are determined at stopping off the engine and subsequent short-term (5–15 seconds) starts for developing the necessary speed of the vehicle and its further movement in the coast mode.

There was proposed a method to reduce fuel consumption in competition conditions by changing the external speed characteristics of the HONDA GX-25 engine with the achievement of the required power and torque at crankshaft rotation with the speed of 4000 min-1. Changes in the external speed characteristic are achieved by increasing the stroke from 26 to 35 mm and the compression ratio from 8 to 11.

The conducted computational study shows that the proposed changes can reduce fuel consumption to provide the necessary power from 300 to 222 g/ (kW • h).

In the CAD/CAE environment of the Inventor system there was created a parametric engine model. Changing the design of the engine consists in installing a composite crankshaft on three supports - roller bearings, which are located in the sump, which is connected with the mono-block engine through a spacer. The additional support of the crankshaft is the necessary condition for equipping the engine with a starting system with an electric starter.

In the future, using the AVL Cruise package there will be carried out computational study of processes occurring in the engine directly in competition conditions.

References

1. Компания Shell // Официальный сайт. – 2013 г. – Режим доступа к сайту: http://www.shell.ua/environment-society/eco-marathon.html
2. Лаборатория скоростных автомобилей ХНАДУ // Официальный сайт. – 2013 г. – Режим доступа к сайту: http://lsa.net.ua/ru/automobile/khadi.
3. Регламент соревнований Shell EcoMarathone // Официальный сайт. – 2013 г. – Режим доступа к сайту: http://s01.static-shell.com/content/dam/shell-new/local/corporate/ecomarathon/downloads/pdf/sem-global-official-rules-chapter-1-2014.pdf.
4. Концерн HONDA. // Официальный сайт. – 2013 г. – Режим доступа к сайту: http://www.honda-motor.su/catalogue/gx-m4_series/gx-25.htm.
5. Технологический университет НАНТ // Официальный сайт. – 2013 г. – Режим доступа к сайту: http://www.la-joliverie.com/projets-edagogiques / micro-joule-cityjoule/.
6. Венгерская команда GAMF автомобиль «мегаметер» // Официальный сайт. – 2013 г. – Режим доступа к сайту: http://energyblog.nationalgeographic.com/2012/05/08/hungarys-megameter-their-knowledge-is-the-fuel-of-the-future/.
7. Компания VEMS параметры топливной аппаратуры автомобиля «Мегаметер» // Официальный сайт. – 2013 г. – Режим доступа к сайту: http://www.vems.hu/wiki/index.php?page=MebersPage%2FShellEcoMarathon.
8. Команда Remmi // Официальный сайт. – 2013 г. – Режим доступа к сайту: http://remmi-team.com/content/vehicles/r7.
9. Американский университет Penn State Behrend. // Официальный сайт. – 2013 г. – Режим доступа к сайту: http://behrend.orgsync.com/org/societyofautomotiveengineers22440.
10. Двигатели внутреннего сгорания: в 3 кн. Кн. 1. Теория рабочих процессов: учебник для вузов / В.Н. Луканин, И.В. Алексеев, М.Г. Шатров и др.; под ред. В.Н. Луканина и М. Г. Шатрова. – 2-е изд., перераб. и доп. – М.: Высш. шк., 2005. – 480 с.
11. Процессы в перспективных дизелях; под ред. А.Ф. Шеховцова. – Х.: Основа, 1992. – 352 с.

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