

Analysis of Fuel Economy in Petrol Engines Due To High Compression of Steppes



Sh.Imomkulov, M.Tukhtaboev

Abstract: All known automotive concerns and institutes specialized in ICE problems have worked to identify the relationship between the compression ratio of ICE and its efficiency and to investigate the nature of thermodynamic processes taking place in ICE. Numerous experiments have also been carried out to increase the compression ratio of ICE. But these works had a negative result. Building on this negative result, ICE theory adopted, as axioms, claims that the compression ratio of a gasoline engine cannot be higher than 14. That the most effective compression ratio of the diesel internal combustion engine is in the region 17-23, and at the compression ratio 40 it becomes zero. Experts and theorists were so established in the correctness of these provisions that at this stage the slightest attempt to question them caused a sharp reaction.

Keywords : thermodynamic cycle, efficiency, combustion engines, Ignition advance angle (IAA), the adiabat.

I. INTRODUCTION

The internal combustion engine is one of those great inventions that, like the wheel, gunpowder, or electricity, have had a tremendous impact on the development of mankind. Its many-sided application is not limited to the sphere of transport. Internal combustion engines account for approximately 40% of the total amount of energy produced on Earth. One of the main indicators by which the work of any heat engine is evaluated is its efficiency. The more heat released during fuel combustion is converted to work, the higher the efficiency. In gasoline internal combustion engines, when operating at full load, more than two-thirds (72-74%) of the internal energy of the fuel used is released into the environment, and less than one-third (26-28%) is converted into work. But when the same engines are running at modes corresponding to loads up to 50% of the rated power (or driving a modern car at a speed of 90-120 km / h), the effective efficiency of a gasoline engine is only 10-12%. The design of modern internal combustion engines (internal combustion engine) for more than a century of engine construction has been brought to perfection. Their mechanical efficiency reaches 80% (and combined-up to 92%). Workflow optimization has also achieved practical

excellence over the past two decades. The use of electronic workflow management programs, injectors that ensure ultra-accurate fuel metering, and the use of direct and multi-stage injection have actually exhausted the reserves for increasing the efficiency of the internal combustion engine. At the same time, a gasoline engine uses about 1/6 of the fuel on average for the benefit of the consumer.

According to the opinion generally accepted in the theory of internal combustion engines, the only way to significantly increase the indicator efficiency of an internal combustion engine is to increase its compression ratio. But the insurmountable obstacle to this was still considered to be the detonation in gasoline engines and the dynamism factor in diesel engines.

II. RELATED WORK

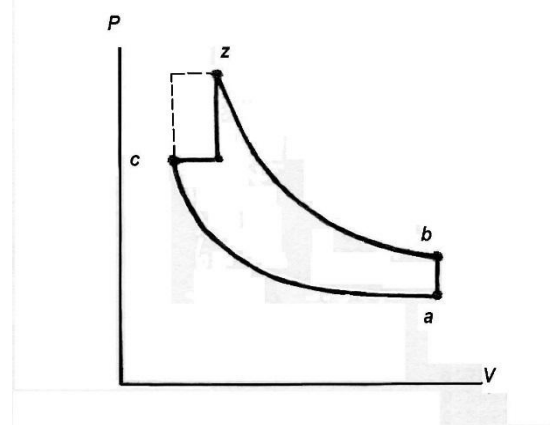


Fig. 1. The thermodynamic cycle Ibadullayev.

Consider the thermodynamic cycle proposed by G.A. Ibadullayev. It is a cycle of heat engine with heat supply first by isobar and then by isochore and heat removal by isochore and with adiabatic compression and expansion processes. For this cycle, expressions of thermal efficiency (not to be confused with indicator efficiency) and average cycle pressure are known. By the way, the thermal efficiency of such a cycle is lower than that of the mixed diesel cycle (heat supply first in the isochron process and then in the isobar process). The thermodynamic cycle proposed by Ibadullayev is always lower in efficiency than the mixed cycle (Sabate-Trinkler) in both thermal efficiency and cycle operation. By the way, this indicates that the process of supplying heat to the expansion line should not be collapsed. Give the formulas of thermal efficiency and average pressure of this cycle:

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Sh.Imomkulov, Assistant of the Department of “General Technical Disciplines”, Namangan engineering and technology institute, Uzbekistan, Namangan. shuhrat19801221@mail.ru

M.Tukhtaboev Assistant of the Department of “General Technical Disciplines”, Namangan engineering and technology institute, Uzbekistan, Namangan, mohirjon3107@mail.ru

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$$\eta_{tib} = 1 - \frac{\lambda \rho^{k-1} - 1}{\epsilon^{k-1} [k(\rho - 1) + \rho(\lambda - 1)]}$$

$$p_{tib} = p_c \frac{[k(\rho - 1) + \rho(\lambda - 1)]}{(k - 1)(\epsilon - 1)} \eta_t$$

In these formulas [epsilon] compression ratio (Va/Vc), [epsilon] - combustion pressure increase ratio (pz/pc), [epsilon] - pre-expansion ratio (Vz/Vc), k - compression adiabat - expansion index.

And here are the known formulas of thermal efficiency and average pressure of the mixed cycle (Sabat  - Trinkler) - diesel cycle with mixed heat supply - first by isochore, and then by isobar:

$$\eta_{tcm} = 1 - \frac{\lambda \rho^{k-1} - 1}{\epsilon^{k-1} [k(\rho - 1) + \rho(\lambda - 1)]}$$

$$p_{tcm} = p_c \frac{[k(\rho - 1) + \rho(\lambda - 1)]}{(k - 1)(\epsilon - 1)} \eta_t$$

At equal compression degrees and values of maximum combustion pressure thermal efficiency and average

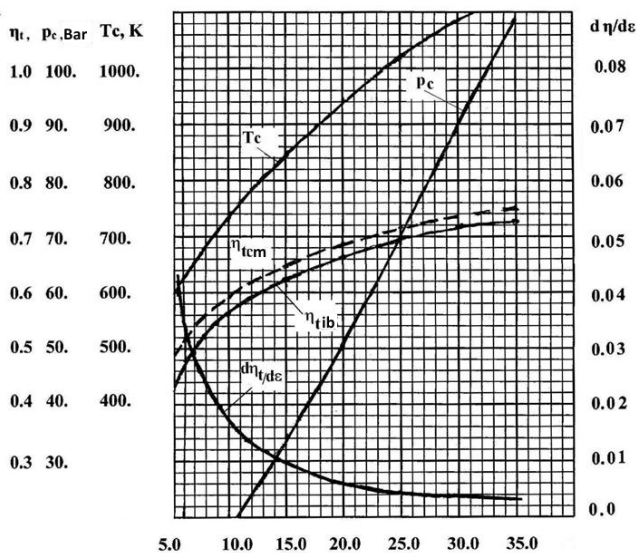


Fig. 2. Dependence of thermal efficiency of η_{tib} pressure P_c and temperature T_c of Ibadullayev cycle compression end on compression ratio

pressure value of mixed cycle (Sabat -Trinkler) always exceed corresponding values of Ibadullayev cycle. This is clearly seen in the following figure. Dashed curve - mixed cycle efficiency.

III. PROPOSED METHODOLOGIES

From the graph, it can be seen that the growth rate of the thermal efficiency value as the compression ratio increases begins to slow down (curve d [theta] t/d [theta]), while the compression end value P_c continues to increase intensively.

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In terms of the actual cycle proposed by the author, it is a cycle of gasoline four-stroke engine with external mixing

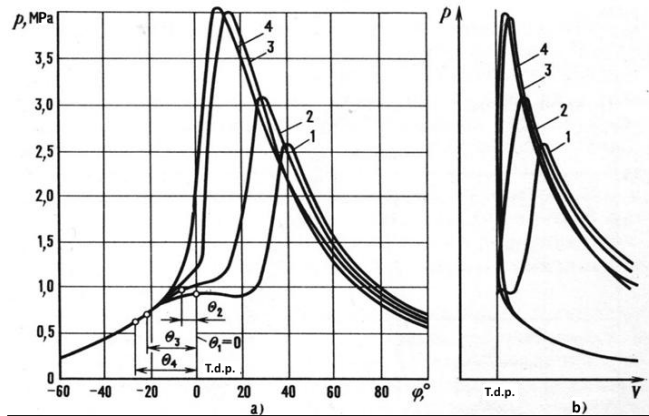


Fig. 3. Fragments of indicator diagrams of engine with forced ignition at different values of ignition advance angle θ : a- ϕ - diagram; b-V ρ - diagram; 1- $\theta_1=0$; 2- $\theta_2=7^\circ$; 3- $\theta_3=22^\circ$

formation, having a difference in adjustments - to reduce detonation ignition of the combustible mixture in the TDC. In all textbooks, since the 1930s it is possible to find indicator diagrams of the actual cycle with values of ignition advance angles close to zero.

Look at curve number 1. This is a valid cycle offered by G.A. Ibadullayev.

It applies only when it is necessary to limit the maximum combustion pressure. Recently, cycles with a small ignition advance angle have been used to limit the emission of nitrogen oxides. The economy always gets worse.

In the thirtieth-fortieth years of the last century, the operation of aircraft engines with high compression rates on high-octane fuels was studied.

The creation of gasoline engines with high compression degrees was abandoned by a number of features of their work:

The desired benefit in the economy of engines with high compression rates was not obtained. The thermal efficiency gains from high compression were offset by increased friction losses due to higher cycle pressures and cost-effectiveness losses from optimal ignition advance angles.

Increased loads in a gasoline engine with a high compression ratio approached it in weight and size terms and cost to diesel engines. Already at a compression ratio of 25, the compression end pressure reaches 71.7 bar.

It is possible to ensure reliable operation of the engine with such cycle parameters by strengthening the parts (increasing the weight and cost of the engine), using more expensive materials (increasing the cost of the engine), improving the control system.

Unfortunately, in his report, the author did not provide reliable certified data on engine start-up qualities, fuel consumption, external characteristics, partial characteristics, load characteristics. I would like to see indicator charts, temperature of parts and gases on the exhaust, assessment of reliability indicators and environmental friendliness. Without this data, it is difficult to judge the effectiveness of increasing the compression ratio.

IV. EXPECTED RESULTS AND OUTCOMES

In general, it can be concluded from the report that the author has achieved major results by organizing satisfactory work without detonating the VAZ engine with a high compression ratio (something about 20-21). But it is clear that such engines will not soon find application. It will be necessary to solve a number of problems on the way to adjusting their design to the level of modern engines in terms of economy, reliability and cost of manufacture.

The result of all this work turned out to be such.

In petrol internal combustion engine with external mixing with ultra-high compression ratio, the operating cycle is as follows: engine compression ratio, for example, is 22, crankshaft speed is higher than 1800 rpm, for example, 2000 rpm, operating mode-external speed characteristic. Under the above conditions, the throttle valve is fully open, the air flow rate is maximum for these revolutions. Ignition advance angle (IAA) 6 degrees to TDC. When the piston is in 0 degrees TDC, flame propagation on the front begins. Up to 6000 rpm the engine operates at fully open throttle, only the IAA changes. When the crankshaft speed decreases below 1800 rpm, for example, to 1200 rpm, the throttle changes position and limits cylinder filling. At that, if at fully open throttle valve the cylinder filling would be 360 mg of mixture, at actual operation at external speed characteristic at specified speed of crankshaft rotation the throttle valve should take such position that maximum inlet of mixture into cylinder should be not more than 270 mg per operating cycle. For an ultra-high compression engine, the notion of external speed performance has a different meaning than for a conventional engine. At low RPM for it is work at maximum permissible filling of the cylinder. It follows from the theory that any disturbance in liquids and gases spreads at the speed of sound. Since the dimensions of the combustion chambers of the piston engines are small and the speed of sound is 500-600 m/s, the pressure through the fractions of microseconds is equalized throughout the volume, but does not remain as in the disturbance zone. Pressure increases in closed vessel of constant volume when gas is heated and pressure and temperature decrease when gas is cooled. If the walls of the volume deform, both volume and pressure increase. The pressure increases in this case less than in the absence of deformation of the walls. As the combustion process begins, the intensity of the heat supply is such that the rate of increase in the pressure of the working medium is faster than the rate of increase in the volume of the chamber. In view of this, it is assumed that it is impossible to equalize the rates of increase in the pressure of the working medium and the volume of the combustion chamber. Therefore, in the combustion chamber there is compression of the mixture zone, to which the combustion front has not yet reached. If the compression rate of the mixture is too high, detonation will occur. However, as mentioned above, by throttling it is possible to control the intensity of the pressure increase of the working medium. And since it can be adjusted, for each particular operating cycle by throttling (limiting the filling of the cylinder), it is possible to select and set a pressure increase rate corresponding to the rate of increase in the volume of the combustion chamber. That is, as it turns out, the process can be synchronized.

Therefore, if the rates of increase of the pressure of the working medium and the volume of the combustion chamber are synchronized during the flame front propagation period, the pressure will remain unchanged. The synchronization process in my engine can be broken in the above three ways: 1. If all data are stored (IAA, air flow rate, mixture composition, etc.), decrease RPM. 2. At preservation of all data (IAA, RPM, mixture composition, etc.) increase mixture consumption. 3. When saving all data, change the IAA. Experiments with synchronization failure were carried out repeatedly. According to the above points, I can give the following data: 1700 RPM, throttle is fully open, design $P_c=60 \text{ kg/cm}^2$. The engine operates without detonation. Reducing the RPM to 1680, i.e. by a total of 20 rpm, causes detonation. Another example: Speed 1680, throttle closed, mixture flow rate 355 mg per cycle. Settlement of $P_c=58 \text{ kg/cm}^2$. There is no detonation. The throttle opens completely. The flow rate of the mixture becomes 360 mg per cycle. The engine detonates. Third example: Moving the ignition angle 10 degrees above or below the optimal point in the engine ZMZ-406 with a compression ratio of 9.5 does not cause any noticeable changes in its operation. In my own engine, the maximum possible displacement of the ignition angle from the optimal point is only 1-1.5 degrees towards its increase and 2-3 degrees towards its decrease. And in the first case there is a strong detonation, and in the second case there is a sharp drop in efficiency. P_c and T_c is the pressure and temperature at the point called the compression end-start of expansion. Once formed at the time of completion of compression, they enter the expansion process as such. Accordingly, the above experimental examples relate to P1 pressure and show that even a minor increase of 2 kg/cm^2 results in detonation P1. Synchronization of the expansion process is a characteristic of the cycle and the basis on which the ultra-high compression engine is built. You can say this: there is synchronization, there is a working engine, there is no synchronization, there is no working engine.

Features of engine indicator operation, as follows:

1). When operating at external speed characteristic

During engine operation from minimum to maximum RPM at external speed characteristic there are 3 zones in which engine operation is built according to completely different principles.

Zone No. 1 (Figures 1 and 6).

This is the filling restriction zone. The existence of this zone distinguishes my cycle from the rest of the known. Zone boundaries depend on engine compression ratio, fuel detonation resistance, etc. For example, for an engine with a compression ratio of 22 using Ai-98 gasoline, the filling limitation zone ends at a crankshaft speed of 1800 rpm. In the specified area, when the engine operates at the external speed characteristic, the throttle valve cannot open by a larger angle (by air flow) than specified in the diagram in Figure 6. The indicator diagram has a step, the heat input starts in the TDC. Constant pressure is ensured during flame propagation along the front P1.

Zone No. 2 (Fig. 2). Said zone consists of 2 transition stages. The first transitional stage. Located behind the filling restriction area. In said zone, the throttle valve is fully open. But heat input begins in the HMT. Ignition angle varies slightly, with correction for speed increase. Width - frequency range, approximately, 100-200 rpm. For a compression ratio engine 22, the first transition stage is completed at a crankshaft speed of 2000 rpm. The existence of the zone is explained by the following: As the speed increases, the compression time of the mixture decreases. Increasing the intensity of compression processes increases the degree of preparation of the mixture for combustion and increases the intensity of combustion processes. Therefore, within the specified frequency range, the start point of the heat input remains in the TDC. The second transitional stage. The length of the stage along the frequency band is 300-500 rpm. In said part of the zone, the heat input point changes to the compression stroke and gradually shifts towards the PMT. In the indicator diagram, the right end of the ledge gradually rises towards Pz. By the end of the second stage of transition zone No. 2, the step disappears completely. Zone No. 3 (Figure 3). In said zone, start of heat injection and start of flame propagation along the front starts at compression stroke. The indicator chart on indicators of Rs and Pz corresponds to the indicator chart of the engine with high extent of pressurization.

2). During operation at partial loads modes.

For an engine with compression ratio 22 at a flow rate of 34% of the air (see Figure 4) from the maximum possible indicator diagram on the indicators Pc and Pz corresponds to an indicator diagram of an engine with compression ratio 10 operating on an external speed characteristic. At further increase of filling depending on RPM the following occurs:

1. If the engine is operating in the area of limitation of filling, a step appears in the diagram as the filling increases.

2. If the engine is operating outside the limit area, Pc and Pz increase to maximum values for this filling.

What is the size of the ledge at the angle of rotation of the crankshaft I do not know exactly. But one is clear. In the area of limitation of filling, the synchronization period must correspond to the period of flame propagation along the front. Otherwise, detonation occurs.

The stated conclusions and decisions did not come together and not immediately. It was a job for several years. Much assistance in practical work was provided to me by M.G. Shatrov. All these years the scientific head of my search was Ivaschenko N.A. Today 's message is not only the result of my work, but also to a large extent the result of the selfless assistance they gave me. Thinking with the help of Ivaschenko N.A. the work done led me to the conclusion that there was not just a solution to get rid of detonation in the gasoline engine and unacceptable rigidity in the diesel engine. A thermodynamic cycle has been opened, which will allow to build ICE with the most efficient compression degrees and the most achievable efficiency.

Why do I think I have the right to talk about the thermodynamic cycle? Because none of the existing cycles can provide operation of ICE with ultra-high compression

degrees. None of the cycles contain such a consistent set of features that my cycle has. Therefore, it is new and will be located in a number of existing cycles, as a separate and independent phenomenon.

V. CONCLUSION

In the work "Theory and Design of Rational Thermal Engine," R.Disel gave a description of the device and principle of ICE operation built according to the "Carnot cycle." Diesel initially assumed that on the adiabatic compression cycle the air was compressed to a pressure of 90 kg/cm² and a temperature of 900 * C, then on the isothermal expansion cycle heat was smoothly introduced and isothermal, then adiabatic expansion should occur at the specified temperature. Under these conditions, the efficiency of the ICE was to be 73%. However, the built engine showed that it made errors in calculations. The heat cost of compressing the air was so high that the engine power was predicted. But after reducing the compression pressure to 35 kg/cm², the engine showed results that were considered fantastic at that time.

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AUTHORS PROFILE



Sh.Imomkulov, Assistant of the Department of "General Technical Disciplines", Namangan engineering and technology institute, Uzbekistan, Namangan. shuhrat19801221@mail.ru.



M.Tukhtaboev Assistant of the Department of "General Technical Disciplines", Namangan engineering and technology institute, Uzbekistan, Namangan, mohirjon3107@mail.ru.