

## THE DESCRIPTION OF THE TOTAL EFFICIENCY OF 2SZ-FE ENGINE WITH THE VARIABLE VALVE TIMING

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### Abstract

In this paper there were conducted tests of the combustion engine with the Atkinson cycle and with applying variable valve timing. There was described the 2SZ-FE engine characteristics and assigned the total efficiency before and after application of the phase shifter.

Secondly, there was determined the thermal efficiency of the single engine work cycles and also engine's total efficiency by using the optoelectronic pressure sensor and mathematical programme. After that, it was available to present the range of the variable valve timing.

Atkinson system, phases of 2SZ-FE engine timing gear, the total efficiency distribution during 75 % of throttle opening and when inlet valves are open, the total efficiency increase during 75 % of throttle opening, the total efficiency distribution during 50 % of throttle opening and when suction valves are open, the total efficiency increase during 50 % of throttle opening, the total efficiency distribution during 25 % of throttle opening and when inlet valves are opened, the total efficiency increase during 25 % of throttle opening, the total efficiency distribution with application of phases shifter are presented in the paper.

**Keywords:** combustion engine, Atkinson cycle, combustion, total efficiency, engine

## OKREŚLENIE SPRAWNOŚCI OGÓLNEJ W SILNIKU 2SZ-FE Z ZASTOSOWANIEM ZMIENNYCH FAZ ROZRZĄDU

### Streszczenie

W pracy przedstawiono wyniki badań przeprowadzonych na silniku spalinowym realizującym obieg Atkinsona z zastosowaniem zmiennych faz rozrządu. Wyznaczono charakterystyki silnika 2SZ-FE oraz określono sprawność ogólną przed i po zastosowaniu przesuwnika fazowego. Następnie przy pomocy optoelektronicznego czujnika ciśnienia oraz programu matematycznego określono sprawność cieplną poszczególnych cykli pracy silnika oraz sprawność ogólną silnika, co umożliwiło ustalenie zakresu zmiany faz rozrządu.

W artykule przedstawiono w szczególności system Atkinson a, fazy rozrządu dla silnika 2SZ FE, przebieg sprawności ogólnej podczas 75 % otwarcia przepustnicy, gdy zawory wlotowe są otwarte, przyrost sprawności ogólnej podczas 75 % otwarcia przepustnicy, przebieg sprawności ogólnej podczas 50 % otwarcia przepustnicy, gdy zawory ssące są otwarte, przyrost sprawności ogólnej podczas 50 % otwarcia przepustnicy, przebieg sprawności ogólnej podczas 25 % otwarcia przepustnicy, gdy zawory wlotowe są otwarte, przyrost sprawności ogólna podczas 25 % otwarcia przepustnicy, przebieg sprawności ogólnej z zastosowaniem zmiany faz.

**Słowa kluczowe:** silnik spalinowy obieg Atkinsona, spalanie, sprawność ogólna, silnik

### 1. Introduction

In 1882 James Atkinson discovered the cycle with extended stroke. It was a noticeable improving of engine's efficiency. Figure 1. presents the first design with different length of the compression and expansion stroke. [5], [11], [8].

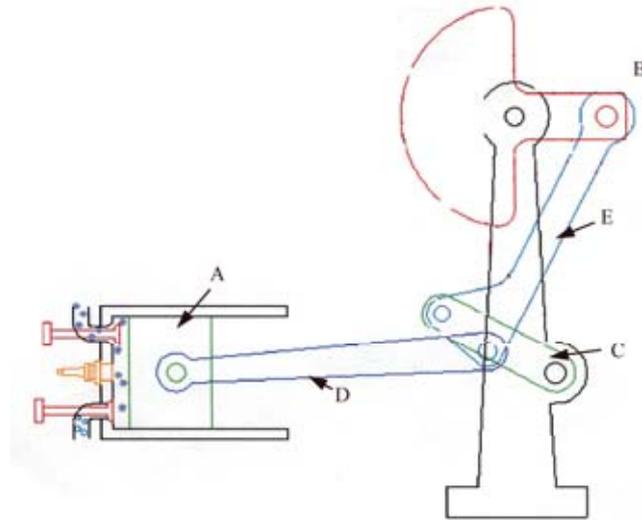


Fig. 1. Atkinson system

*During every crankshaft rotation (B) piston (A) moved by connecting-rods (D and E) will make two pairs of up-down strokes. When the lower support's point of lever (C) will be in some distance from piston's axle, the piston's stroke in both pairs of strokes will be different*

The Atkinson system was unpractical, so constructors used engines with single connecting-rod. In such situation all pistons' strokes had the same length. In the ordinary driving unit piston's stroke determines the scale of its work only in limited range. The points of valve's open and close also ignition's point are never the same as lower and upper piston's dead centre.

Nowadays it is possible to adopt the Atkinson cycle by using the variable phase of timing gear with hydraulic or electric control and also variable geometry of air inflow for defined engine's parameters.[1],[3].

In this paper is described the effect of increase of engine's total efficiency after use of Atkinson cycle. Phenomenon which take place in cylinder is simulate by computer,

The application of computer simulation and mathematical patterns were helpful during preparing constructional presumptions and also gave the opportunity to design any shapes of cooperating elements in order to achieve the best results.

## **2. The description of the total efficiency increase in 2SZ-FE engine after using the phase's shifter**

The engine brake was installed on research stand in order to measure the pressure and combustion in engine cylinder of vehicle.

The 2SZ-FE engine was located on research stand which was specially prepared for conducting researches of load, the variable phases of timing gear and exact instrument reading of:

- torque,
- rotational speed,
- cylinder pressure,
- crankshaft position,
- camshaft position,
- mass fuel flow rate,
- toxic of exhaust gases,
- coefficient of air excess.

The total efficiency was described on the basis of researches of 2SZ-FE engine (Table 1); the opening of inlet valves for: 30° BTDC, 20° BTDC, 10° BTDC, in TDC, 12° ATDC. [2] [7] [9].

The Figure 2 presents the range of the variable valve timing.

Tab. 1. The values of 2SZ-FE engine

System of timing gear	16 valves DOHC (VVT-i)
Piston displacement [cm <sup>3</sup> ]	1298
Bore [mm]	72
Stroke [mm]	79,7
Compression ratio	10 : 1

↗ : The timing gear phases of suction valve  
 ↘ : The timing gear phases of exhaust valve

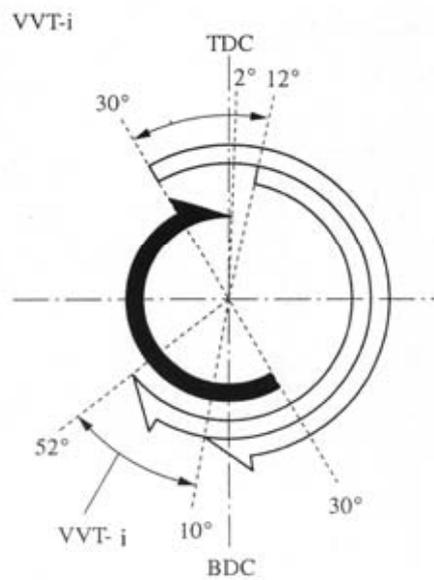


Fig. 2. Phases of 2SZ-F Engine timing gear

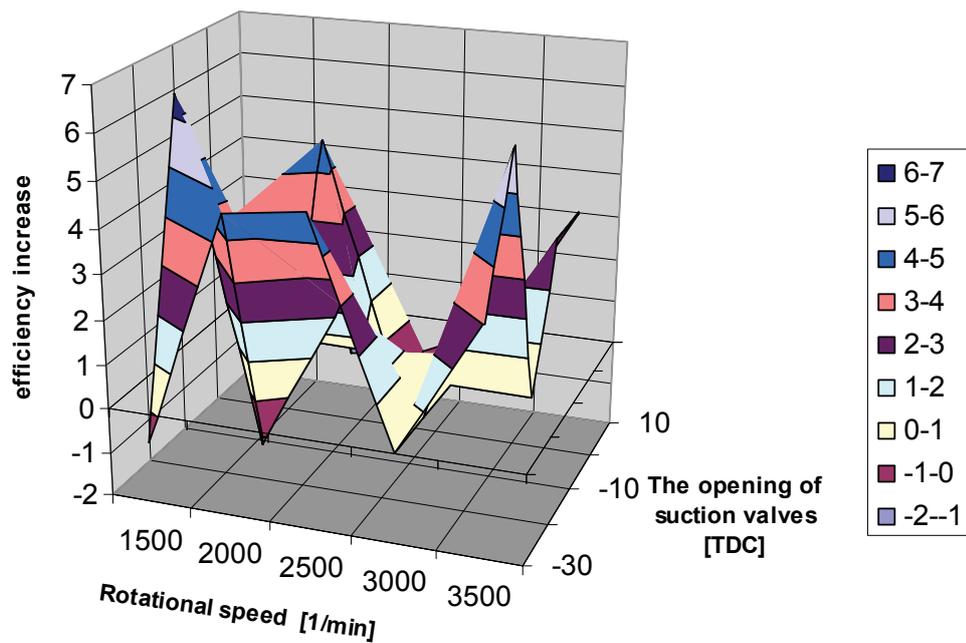


Fig. 3. The total efficiency distribution during 75 % of throttle opening and when inlet valves are open:  
 a) 30<sup>0</sup> BTDC, b) 20<sup>0</sup> BTDC

Figures 3, 5, 7 present the distribution of the total efficiency for particular arrangement of camshaft. In specified scale of engine work 15 % of efficiency increase was noticed. Figure 4 presents the max increase of total efficiency when rotational speed was circa 2000 [revolution per min] and inlet valves were opened in TDC. The 5 % increase of the total efficiency was registered when inlet valves were opened 30° BTDC and rotational speed was 2300 [revolution per min]. [4], [6].

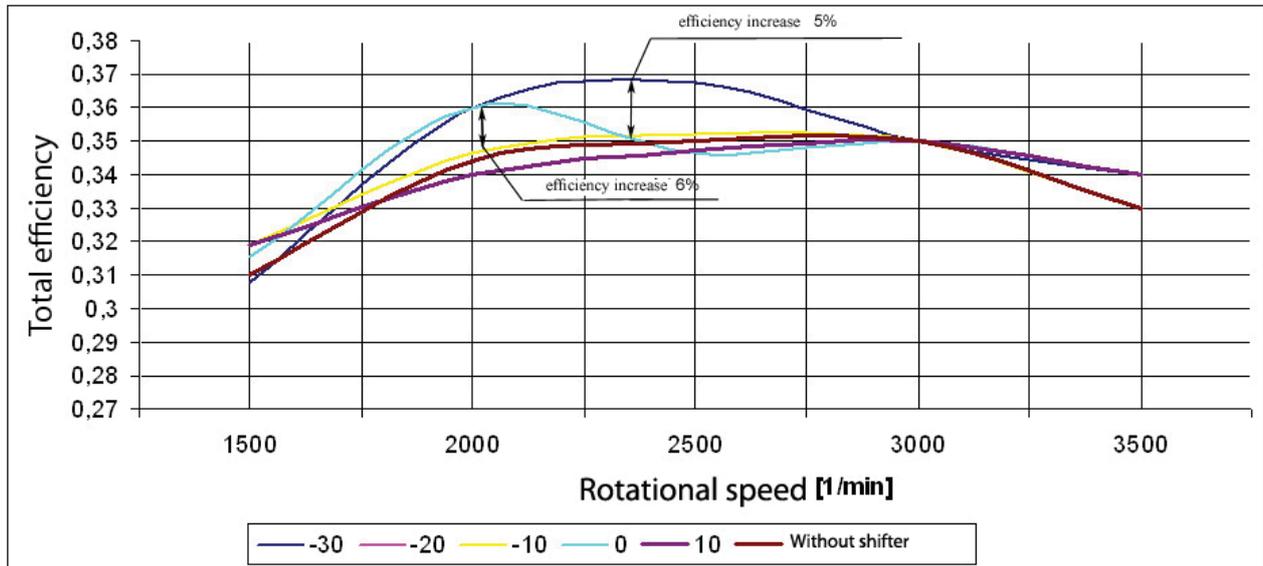


Fig. 4. The total efficiency increase during 75 % of throttle opening

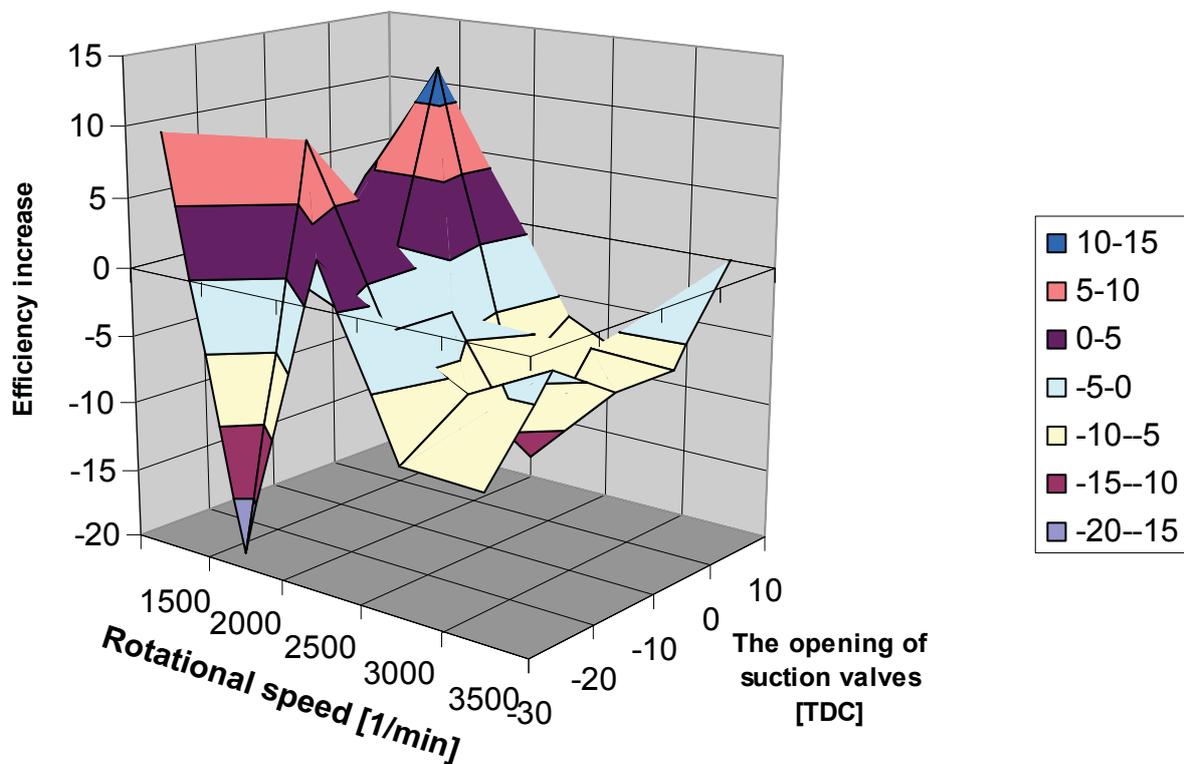


Fig. 5. The total efficiency distribution during 50 % of throttle opening and when suction valves are open:  
a) 30° BTDC, b) 20° BTDC

The total efficiency increase while inlet valves are opened in TDC and 50% of throttle opening are presented on Figure 6 (max increase during rotational speed of 2000 [revolution per min]).

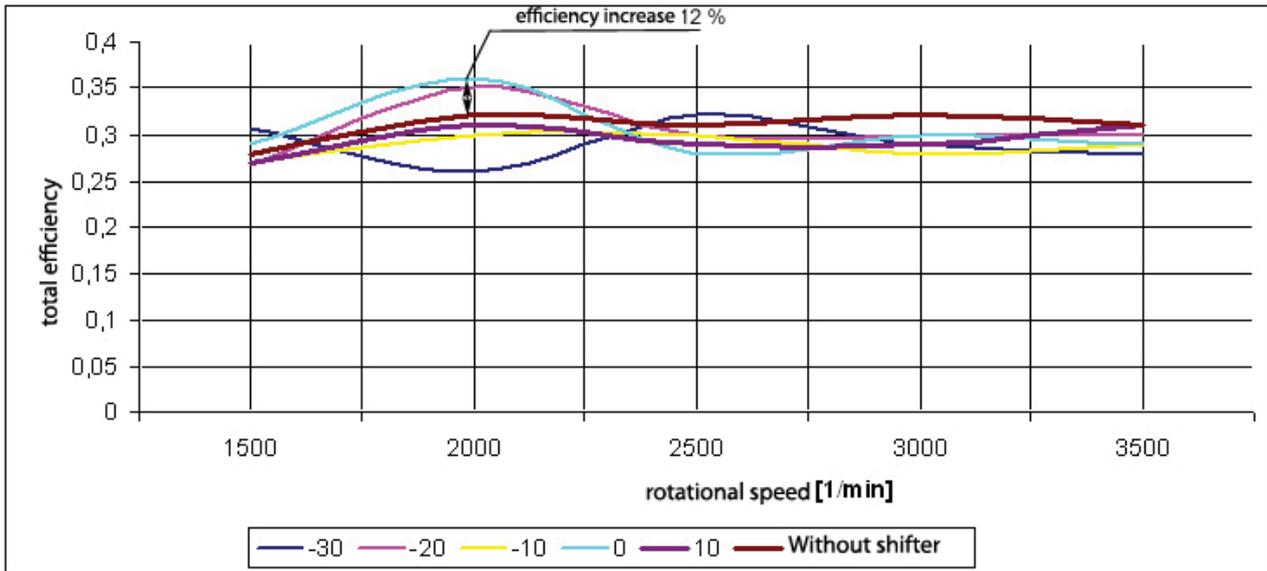


Fig. 6. The total efficiency increase during 50 % of throttle opening

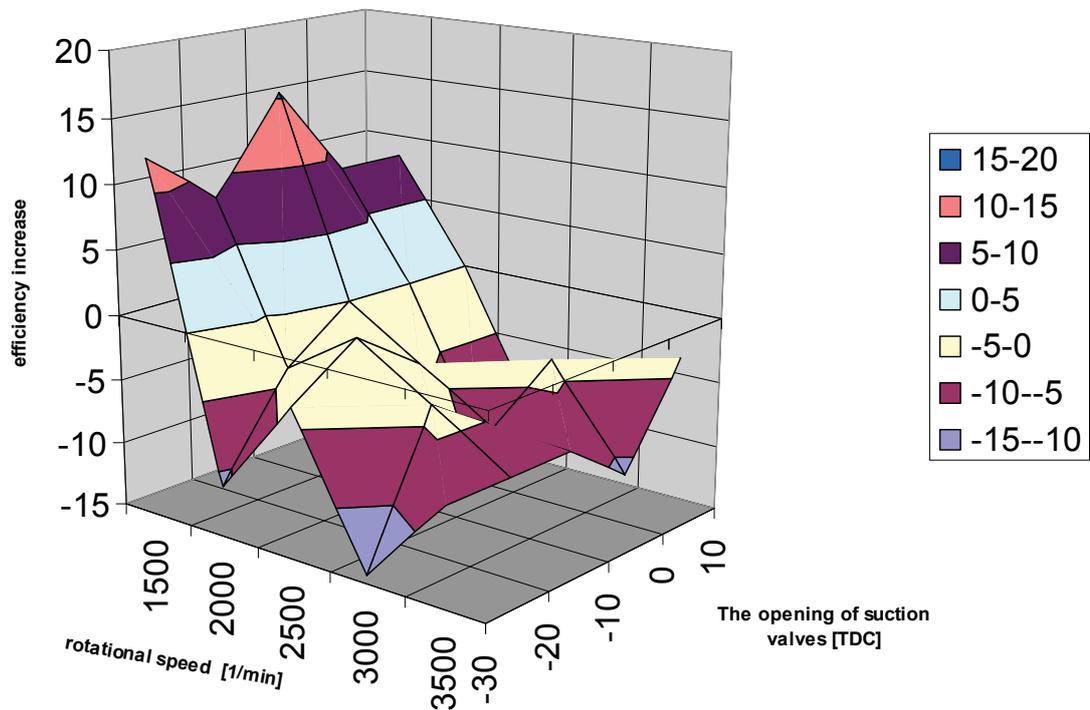


Fig. 7. The total efficiency distribution during 25 % of throttle opening and when inlet valves are opened:  
 a) 30° BTDC, b) 20° BTDC

Figure 8 presents the total efficiency increase while inlet valves are opened 10° BTDC and 25% of throttle opening. Maximal increase - at rotational speed of 1500 [revolution per min]).

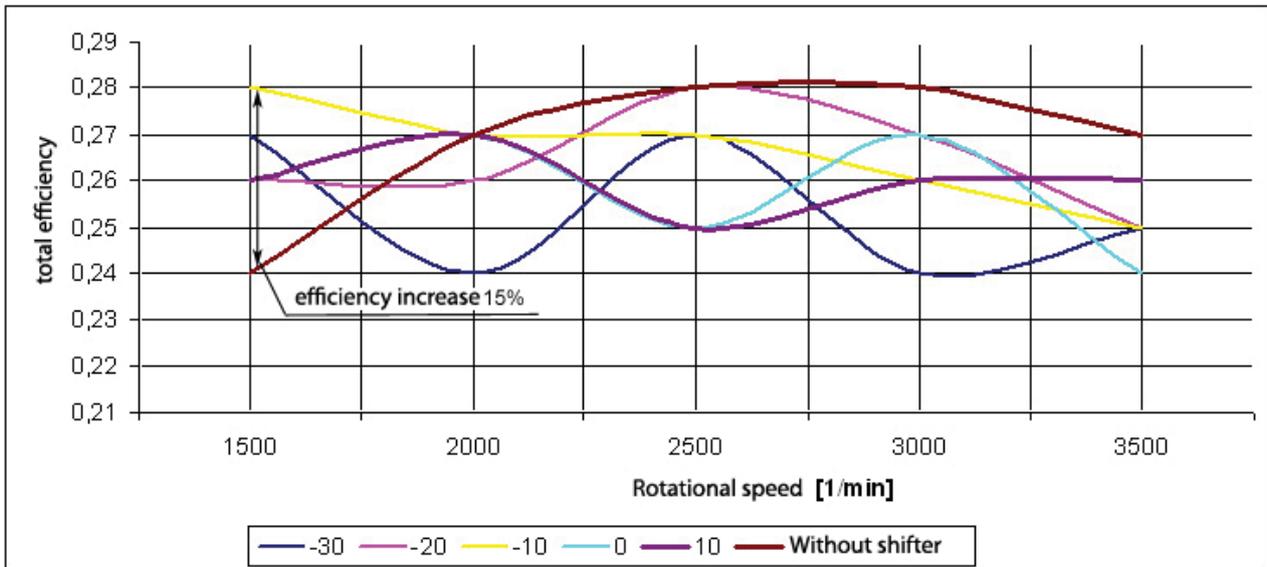


Fig. 8. The total efficiency increase during 25 % of throttle opening

On Figure 9 was presented the general listing of the total efficiency increase. The maximum value of the total efficiency we can receive while inlet valves are closed 10° ATDC and 25% of throttle opening and rotational speed is 1500 [revolution per min].

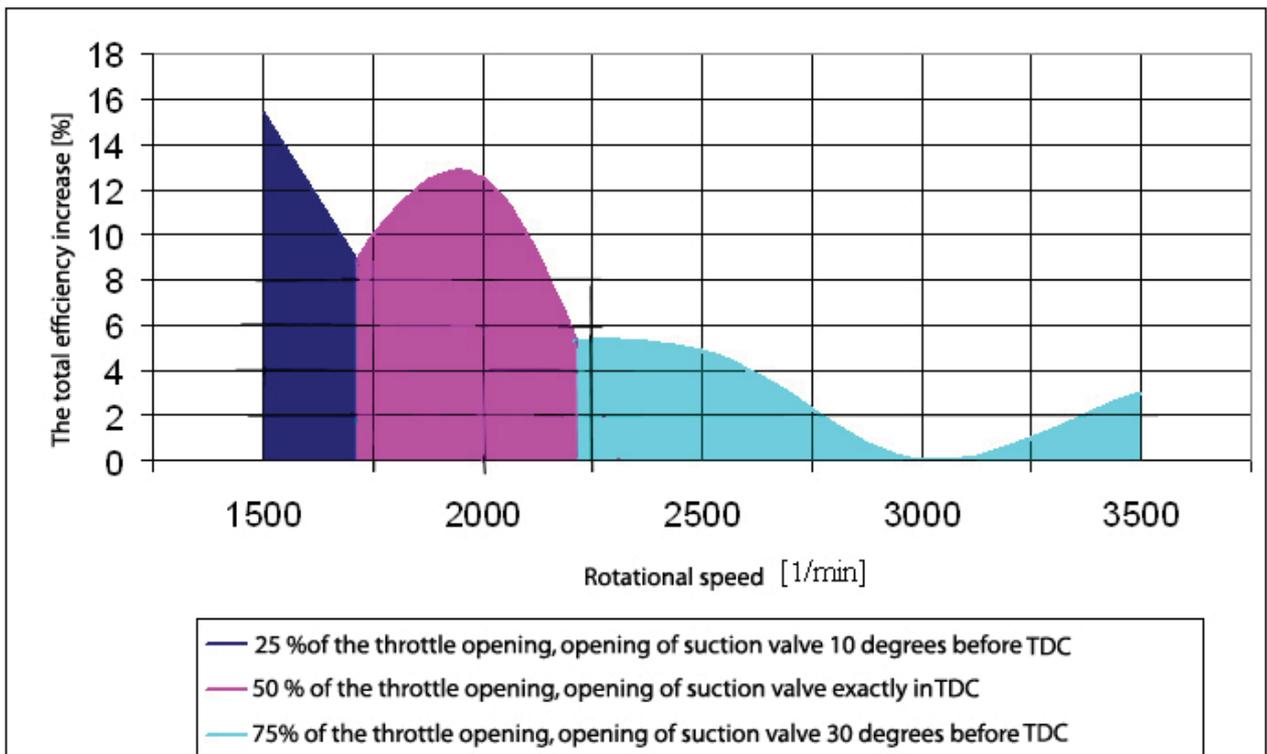


Fig. 9. The total efficiency distribution with application of phases shifter

By using the phase's shifter of suction valves we can notice the increase of total efficiency in range to 3500 [revolution per min]. The main defect of the hydraulic system of camshaft position is problem with maintenance of particular values during thermal stabilization of engine oil.

### 3. Conclusion

On the base of paper “The description of the total efficiency 2SZ-FE engine with the variable valve timing” we can derive some conclusions:

1. By using the phase's shifter we can notice 12% increase of total efficiency while inlet valves are opened in TDC and 50 % of throttle opening.
2. The 15 % increase of total efficiency while inlet valves are opened 10° BTDC and 25 % of throttle opening.
3. The possibility of verification of the total efficiency in control range of camshaft: 30° BTDC - 12° ATDC.
4. The possibility of obtainment of the total efficiency increase in the range of rotational speed 1500-3000 [revolution per min].

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