JOURNAL OF ENGINEERING
annals OF
FACULTY OF ENGINEERING HUNEDOARA
TOME VI (year 2008), FASCICULE 1, (ISSN 1584 – 2665)

INFLUENCES OF SI ENGINE PARAMETERS ON CREVICE FUEL LOSSES

Kiril HADJIEV

University of Rousse, Bulgaria

ABSTRACT:
Some aspects of crevice influence on fuel losses under different air-fuel mixtures and engine load were presented. Quantitative estimate of fuel losses were done. The real fuel losses (around 4% from cycle fuel amount) are larger than HC concentration measured in exhaust gases. These losses reduce significantly engine efficiency. It is possible to reduce these losses with lean mixtures and with stratified charge.

KEY WORDS:
SI engine, ring-crevice, two-zones model, fuel losses, pollutant emissions

1. INTRODUCTION

Many detailed investigations on hydricarbon sources in spark ignition engines have been conducted to meet stringent emission requirements. Hydrocarbon emissions result from the presence of unburned fuel in the engine exhaust. Table 1 shows the about 9% of the fuel supplied to the engine is not burned during the normal combustion phase of the expansion stroke. As a consequence hydrocarbon emissions cause a decrease in the thermal efficiency, as well as being an air pollutant [1].

Table 1

SOURCE	% FUEL ESCAPING NORMAL COMBUSTION	%HC EMISSIONS
Crevices	5.2	38
Oil layers	1.0	16
Deposits	1.0	16
Liquid fuel	1.2	20
Flame quench	0.5	5
Exhaust valve leakage	0.1	5
Total	9.0	100

Total crevise volume is few percent of the clearance volume [2] and the piston and ring pack crevices are the dominant contributor. Piston-ring crevice has been suggested as a major source of engine-out hydrocatbon emissions.

As the cylinder pressure rises during compression, unburned mixture is forsed into the crevice regions. The gas flowing into each crevice cools by heat transfer to the wall temperature. During combustion, while the pressure rises, unburned mixture continues to flow into the crevice volumes (density higher than cylinder gas since gas is cooler near walls). After flame arrival ring crevice quenching. When cylinder pressure decreases gas flows back from crevice into the cylinder. Depending on spark plug location in relation to the position of the top ring gap, well above 50 percent of this can be unburned fuel-air mixture [3]. One part of the fuel can oxidize during exhaust, but the other part is a source for about 40% of the whole amount HC be released with exhaust gases.

The fuel amount in ring crevice strongly depends on the composition of the mixture and the engine load. For determination of how it affects at alteration of these parameters two-zones combustion model for homogenous charge engines is used.

2. THERMODYNAMIC MODEL

The combustion chamber was generally divided into burned and unburned zones separated by a flame front. The first law of thermodinamics, equation of state and conservation of mass and volume were applied to the burned and unburned zones. The pressure was assumed to be uniform through-out the cylinder charge. A system of first-order ordinary differential equations (1-6) is obtained for the pressure, mass, volume, temperature of the burned and unburned zones, heat transfer and mass flow into and out of crevice.

$$m = m_u + m_b \qquad (1)$$

$$V = V_u + V_b \qquad (2)$$

$$\frac{d(m_u u_u)}{d\varphi} = -p\frac{dV_u}{d\varphi} - \frac{dQ_u}{d\varphi} - h_u\frac{dm_{ucr}}{d\varphi} + h_u\frac{dm_{uR}}{d\varphi} \qquad (3)$$

$$\frac{d(m_b u_b)}{d\varphi} = -p\frac{dV_b}{d\varphi} - \frac{dQ_b}{d\varphi} - h_b\frac{dm_{bcr}}{d\varphi} + h_u\frac{dm_{bR}}{d\varphi} \qquad (4)$$

Change of mass flow to the crevice is:

$$\frac{dm_{cr}}{d\varphi} = \frac{V_{cp}}{RT_W}\frac{dp}{d\varphi} \qquad (5)$$

Change of mass of working gases in the cylinder as a result flow to the crevice is:

$$\frac{dm}{d\varphi} = -V_{cr}\frac{dp/d\varphi}{R_{cm}T_W} = -\frac{dm_{cr}}{d\varphi} \qquad (6)$$

where: m, V, u, h correspond to – mass, volume, specific energy and enthalpy, Q – heat transfer to the walls, m_{cr} – mass flow to the crevice, dm_R – change of mass as a result of combustion, T_w - temperature of wall and V_{cr} – volume of ring-crevice.

With suffix "u" is marked the air-fuel mixture and with "b" – burned gases.

The research was conducted with engine ACME VT88 (Bore: 88mm, Stroke: 79mm) with crevice volume V_{cr}=0,497.10^{-6}, as it is assume cone combustion chamber with a central located spark plug.

3. RESULTS

The investigation shows that the amount of air-fuel mixture enter in ring-crevice depends on the alteration of in-cylinder pressure (fig.1). This amount is largest when the pressure is maximum. After that it decreases under back flow from crevice to combustion chamber.

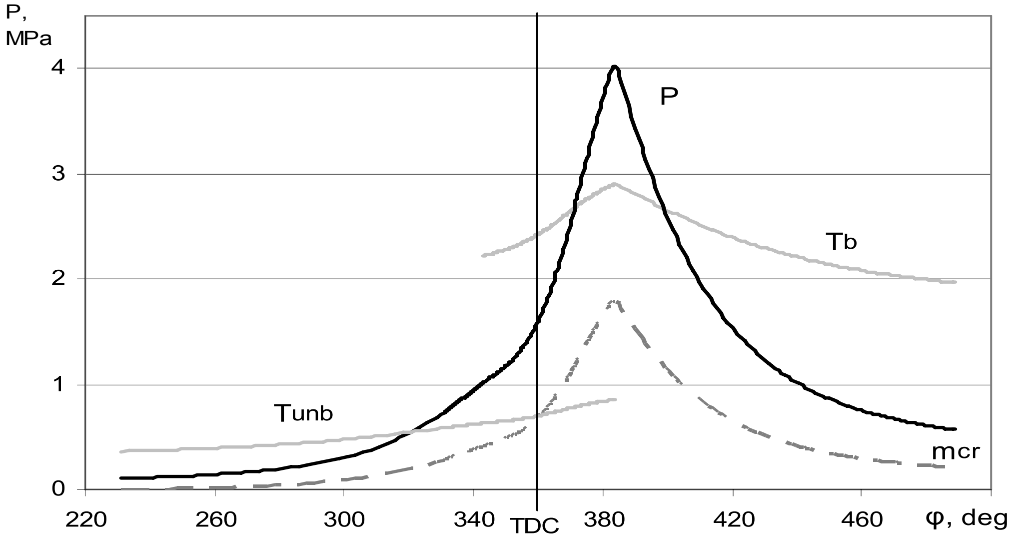

Fig.1. Cylinder pressure P, Tunb, Tb and m_{cr} versus crank angle

During combustion, the flame quench when reaches crevice due to relatively low temperature of the walls. The real loss of air-fuel mixture is its amount in the crevice at the time when flame quench..

More significant is the amount of fuel in the ring crevice. On the one hand this fuel doesn't burn and decreases the efficiency, on the other hand – a large part of it cannot oxidize during expansion and it causes highest HC emissions. The air-fuel mixture flows back to the cylinder with pressure drop after exhaust valve opening leads to HC rise.

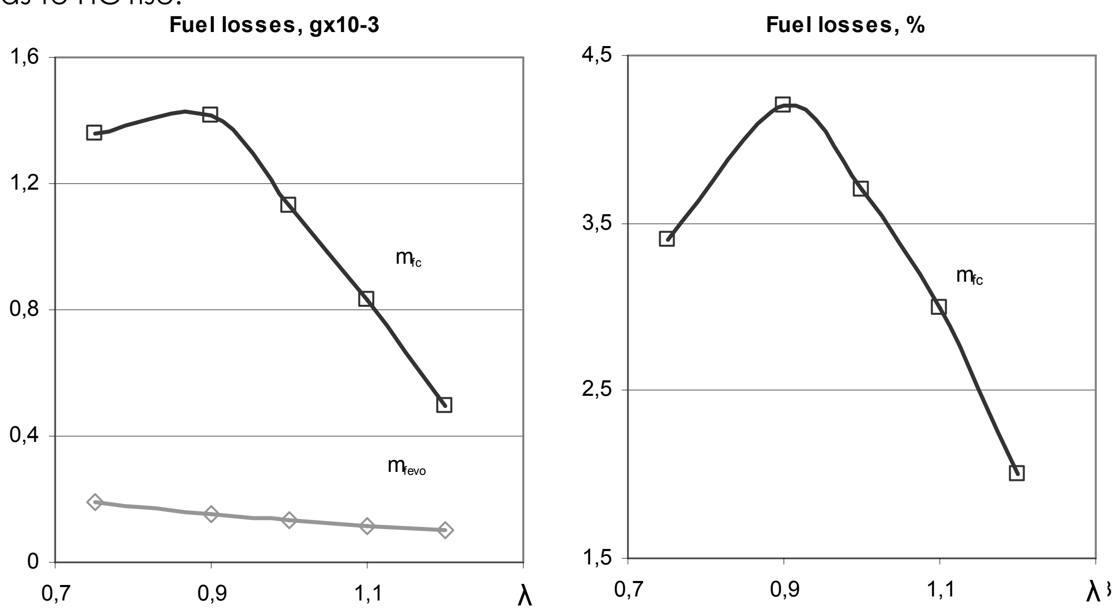

Fig.2. Fuel losses at the end of combustion m_{fc} and at the exhaust valve oppening m_{evo} versus air-fuel ratio λ. a –mass fuel loss, b – fuel loss as percentage of total cyclic fuel amount.

Another factor, affecting the fuel losses, is the air-fuel ratio. For rich air-fuel mixture there will flow more fuel in the crevice. It is evident on Fig.2. that with farther richness of mixture amount of this fuel decreases, because of lower maximal pressure in the cylinder.

The losses of fuel at the end of combustion with stoichiometric mixture is arround 4% and with lean mixture it decreases (at λ=1.0 it is 2%). The further decrease of the losses, through more leane mixture, is limited because of unsteady work and change for the worse of the engine. Significant effect will be achieved with stratified air-fuel mixtures. The amount of fuel in the crevice in the moment of opening of exhaust valve is below 0,5%.

Engine load influences on crevice fuel losses as well. It can be seen on Fig.3.

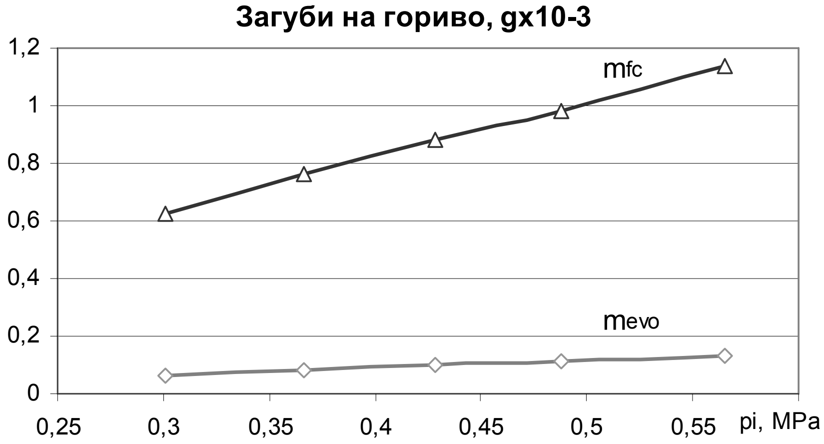

Fig.3. Fuel losses versus mean indicated presure p_i.

Investigation is made for stoichiometric mixture. It is evident that the fuel amount in the crevice at the end of combustion increases more intensively than this at the exhaust valve opening.

It must be assumed, that the investigation is carried out for case with central located spark plug. At different location of spark plug the fuel losses will be less, because of short flame propagation and at maximal in-cylinder pressure there will be burn gases flowing into crevice.

4. CONCLUSION

The real fuel losses (around 4% from cycle fuel amount) are larger than HC concentracion measured in exhaust gases. These losses reduce significantly engine efficiency. It is possible to reduce this losses with lean mixtures and with stratified charge.

REFERENCES

[1.] Choi H., Kim S., Oxidation of Unburned Hwdrocarbons from Crevices In Spark-Ignition Engines, COMODIA 2001 July 1-4, Nagoya

[2.] Heywood J. B., Internal Combustion Engine Fundamentals, II Series 1988, ISBN 0-07-100499-8

[3.] Heywood J. B., Keck J. C., Hydrocarbon Formation and Oxidation in Spark-Ignition Engine, Final Report, August 1979