Development Prospective of EGR System Applied on Gasoline Engine—A Review

Li Wang
Xuanchong Vocational and Technical College, Xuancheng, China

Zhaoming Huang
Hehai University, Wentian College, Maanshan, China

Qi Zeng
Luzhou Vocational & Technical College, Luzhou, China

ABSTRACT: With the fuel consumption regulations and emission standards becoming more and more stringent, many new technologies have been used on gasoline engine, and applying EGR (Exhaust Gas Recirculation) system on gasoline engine is becoming a mainstream. On the basis of giving an introduction to high pressure and low pressure EGR architecture, this paper has elaborated the principle of EGR system, analyzing the advantages of EGR. Then the brake specific fuel consumption improvement of EGR has been put forward with the universal curves of gasoline engine, and emission reducing function of EGR was analyzed and explained. Finally, a conclusion was drawn that EGR system will be a necessary factor of modern gasoline engine.

1 GENERAL INSTRUCTIONS

EGR turned up in the 1960s, and it was used firstly on gasoline engine to improve the combustion stability at idle speed. Because of EGR can make the cylinder combustion temperature decline, then EGR technology was applied on diesel engine to reduce NOx emission. However, with the gasoline engine technology booming, EGR now has been a factor of gasoline engine to improve economy and exhaust gas emission.

Because of fuel environment protection and shortage of fossil resource, Chinese government has published the vehicle fuel consumption regulations. In 2020, the fourth stage fuel consumption standard will be carried out, and the regulation is 5L/100km, being equal to 117g CO2/km. It is forecast that in 2030 the case of that is 3.0L/100km. It has big pressure to the vehicle OEM. The detailed data is shown in figure 1.

![Image of fuel consumption standards and regulations]

Figure 1. Chinese fuel consumption standards and regulations.
EGR can keep gasoline engine combustion stable at idle speed. When the engine is running at part load points, EGR can make the pump loss of engine decline, achieving the goal of reducing fuel consumption. When the engine is operating at maximum load of low rotating speed, EGR can make the cylinder combusting temperature keep at relatively low level, and the spark ignition angle can be advanced, using more radical spark angle, then the combustion gravity core being advanced, finally improving the engine's thermal efficiency. When the engine is running at maximum load of high speed, EGR can depress exhaust temperature, and the strategy of no enrichment can be carried out, attaining the target of saving fuel. Furthermore, the flexible and optimizing applying technology can also improve the engine's emission.

2 OVERVIEW OF GASOLINE ENGINE EGR SYSTEM

2.1 Gasoline engine high pressure EGR and low pressure EGR

EGR technology system can be divided into high pressure circuit system and low pressure circuit system, and they are shown in figure 2. The advantages and disadvantages of gasoline engine HP and LP are outlined in table 1.

![Figure 2. High pressure and low pressure EGR system of gasoline engine.](image)

<table>
<thead>
<tr>
<th></th>
<th>Reference</th>
<th>HP EGR</th>
<th>LP EGR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression ratio</td>
<td>0</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td>Part load BSFC</td>
<td>0</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>High load BSFC</td>
<td>0</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Comprehensive BSFC</td>
<td>0</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Corrosion</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost Increment</td>
<td>0</td>
<td>-</td>
<td>--</td>
</tr>
</tbody>
</table>

* 0Reference; ++More superior; +Superior; -Bad; --Worse.

2.2 Introduction to EGR effects on engine performance

In the universal map of gasoline engine, different engine performance improvement can be achieved by means of various EGR strategies. Through different EGR rate, different energy saving targets can be attained. The BSFC (brake specific fuel consumption) improvement and its theory are shown in figure 3.

![Figure 3. BSFC improvement and its theory using EGR.](image)

From figure 3, we can see that in the knock area, 5%~7% energy saving target will be available, and in the part load area, about 7% BSFC improvement
can be carried out by means of increasing compression ratio, while in enriching area, the maximum fuel consumption reducing, up to 15%, has been achieved. Many factors, including pump loss reduction, combustion temperature declining, knock depression, specific heat ratio increasing and compression ratio increasing, can be account for fuel consumption improvement. In the following part, the theory and reason of gasoline engine BSFC improving will be analyzed in detail.

3  EXPLANATION OF EGR APPLYING ON GASOLINE ENGINE EFFECTS

3.1  IMEP and pump loss

The paper [1] has stated that at part load operating point, with the increasing of EGR rate, IMEP (indicated mean effective pressure) increases remarkably. Meanwhile, the PMEP (pump mean effective pressure) becomes smaller when EGR rate increasing, the pump loss decreasing. The detailed results are shown in figure 4.

![Figure 4. EGR effects on IMEP and PMEP of gasoline engine.](image)

From figure 4, we can see that with EGR rate increasing, the IMEP performance improves while PMEP declines. The formula (1) can be used to describe the PMEP’s contribution to IMEP improving.

\[
\epsilon = \left( \frac{\Delta_{\text{PMEP}}}{\Delta_{\text{IMEP}}} \right) \times 100\%
\]

Where \(\epsilon\) = the proportion of PMEP declining value of IMEP increasing value; \(\Delta_{\text{PMEP}}\) = PMEP declining value; and \(\Delta_{\text{IMEP}}\) = IMEP increasing value.

In the figure 4, when EGR rate is set to 5%, \(\epsilon\) has the maximum value 96%. And when EGR rate is fluctuating between 0%~20%, the \(\epsilon\) is above 50%. This data indicates that when EGR rate is between 0%~20%, the declining of PMEP contributes more than 50% to IMEP improvement, the reason for which is that with EGR rate increasing, the throttle enlarges, resulting in the intake pressure increasing.

3.2  EGR effects on pre-ignition

Paper [2] has investigated the effects of EGR on Pre-ignition events. The testing engine's compression ratio is 10.0. The operation point is 1250rpm@13bar, with the intake temperature 60℃ and EGR temperature 90℃, using stoichiometric air fuel ratio. EGR rate is changing from 6% to 10%. Test results are shown in figure 5.

Figure 5 shows that adopting EGR strategy on gasoline engine can depress the pre-ignition frequency. After completion of EGR test, then base engine test with no EGR were done, and it is found that pre-ignition events occurring is higher than normal base engine. The reason for pre-ignition can be interpreted as some kind of accumulation mechanism.

![Figure 5. EGR effects on pre-ignition of gasoline engine.](image)

Because EGR can reduce abnormal combustion event on gasoline engine, more radical ignition angle can be used to achieve higher combustion efficiency. Therefore, the BSFC improvement at low speed with full load can be available.

3.3  EGR effects on high load

Paper [3] analyzed the BSFC improvement with WCEM (water cooled exhaust manifold) and EGR on a 1.4TGDI engine. At 3500rpm and 4000rpm, with corresponding torque 240N.m, because of using LP EGR system, no enrichment comes into true practice. The test results are shown in figure 6.

![Figure 6. BSFC benefit with WCEM and EGR.](image)
When the enrichment is eliminated at high speed with maximum load point, the fuel can be saved by 3%~6%.

EGR can make the cylinder combustion temperature decline, so the engine does not need enrichment to depress exhaust temperature, resulting in energy saving finally.

3.4 **EGR effects on combustion characteristic**

EGR’s effects on engine combustion characteristic can be found in the paper [4]. The test engine’s displacement is 1.5L, with compression ratio 11.5. When the engine is operating at 3000rpm@10bar, the combustion characteristics changing with EGR ratio are shown in figure 7, figure 8 and figure 9.

![Figure 7: In-cylinder pressure and heat release ratio changing with EGR rate.](image1)

![Figure 8: BSFC and indicated thermal efficiency changing with EGR rate.](image2)

![Figure 9: CA50 and exhaust gas temperature changing with EGR rate.](image3)

From figure 7, figure 8 and figure 9, we can see that with EGR rate increasing, the peak cylinder pressure and CA50 is advanced, while the peak heat release ratio is delayed, and BSFC declining, indicated thermal efficiency increasing.

4 **CONCLUSIONS**

From what has been discussed in this paper, we can safely come to a conclusion that using EGR system on gasoline engine, BSFC will be improved in all over the universal map. The payment is that corrosion and cost problems should be overcome. Generally speaking, it is believed that EGR is a kind of promising technology in the future.

**REFERENCES**


