Evaluation of Pressure Pulsations in the SGMW B12 T255 Fuel Rail Assembly

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Abstract: The test is investigated magnitude of pressure pulsations in the SGMW B12 T255 fuel rail assembly and any effects on port to port flow distribution. The test bench is provided the fuel rail assembly required pressure and pulse width and period to simulate series of engine work status. The pressure pulsation results showed a significant change in the magnitude between 2000 and 3000 RPM. Flow distribution was further measured at 2000 RPM and 7ms, the finally test result is passed. After the vehicle test, it’s showed that reducing the flow rate from 1.8g/s to 1.5 g/s would further improve pulsation performance.

1. Introduction
Shanghai GM Wuling (SGMW) concerns of poor A/F distribution results on the B12D engine at certain part load conditions. Based on their initial investigations, SGMW requested to provide fuel injectors having better than ±2% flow tolerances. If the flow tolerances are not in±2%, it would lead to additional production fallout, so other solutions would be preferred.

The fuel rail is a returnless rail and is not equipped with a damper. It was thought perhaps high pressure pulsations could be one of the reasons contributing to the poor A/F distribution.

Pressure pulsations measurements on the SGMWB12 T255 fuel rail assembly bench tests were carried out in the Continental Automotive Changchun Ltd Lab in Cell 14, the vehicle tests were carried out in SGMW test room.

Measurements were made at discreet speed and injection time points ranging from 600 to 6000 RPM and 2.2 to 12 ms injection times. The natural frequency of the rail was measured at 45 Hz (1350 RPM) [1].

The magnitudes of the pulsations dropped significantly between 2000 and 3000 RPM. Flow distribution was further measured at 2000 RPM and 7ms, and the result showed less than 1% variation. The vehicle test on the fuel rail assembly was also passed accordingly

2. Test Procedure on bench test:

2.1. Evaluate rail assembly in Test Cell #14 for pulsations
a. Speeds Tested:  600, 1000, 2000, 2400, 3000, 4000, 5000, 6000 RPM
b. Injection Times:  2.2, 3.0, 6.0, 7.0, 8.0, 9.0, 12.0ms
c. Resonance – single pulse of # 1 injector
Test fuel: D40, System pressure: 380kpa, Fire order: 1-3-4-2, Temperature: 21°C, Sampling rate: 20,000Hz, Pulse width: 2ms, 6ms, 12ms.

Test Bench is shown as figure 1:
1. The test bench is provided required pressure to fuel rail assembly
2. The test bench is provided required pulse width and period to simulate series of engine work status

Test sample shown as Figure 2: Fuel Rail Assembly including
1. FR, stainless steel 15x15x1mm section;
2. Injector, 109261, 1.5g/s at 380kpa.

2.2. Measure port to port flow distribution at approximated part load condition

3. Bench test results and conclusions
The SGMW B12 T255 fuel rail assembly pressure pulsations (kPa Peak to Peak) test results is showed the pressure on such test speed & injection time as Table 1.

| Speed (RPM) | 2.2 | 3.0 | 6.0 | 7.0 | 8.0 | 9.0 | 12.0 |
|-------------|-----|-----|-----|-----|-----|-----|------|
| 600         | 28.00 | 34.24 | 62.83 | 69.18 | 76.01 | 76.71 | 76.01 |
| 1000        | 23.88 | 29.30 | 52.24 | 63.06 | 67.06 | 68.71 | 67.06 |
| 2000        | 26.83 | 34.83 | 66.89 | 72.48 | 64.71 | 70.59 | 46.36 |
| 2400        | 37.30 | 38.59 | 60.95 | 57.65 | 59.30 | 50.59 | 20.24 |
| 3000        | 22.83 | 18.59 | 26.59 | 20.12 | 22.35 | 18.12 | 23.53 |
| 4000        | 26.35 | 28.59 | 26.24 | 16.47 | 9.18 | 22.59 | 29.41 |
| 5000        | 16.00 | 19.06 | 9.53 | 18.24 | 22.00 | 22.00 | 9.53 |
| 6000        | 14.82 | 14.82 | 16.94 | 19.77 | 21.41 | 21.18 | 17.41 |

At the speed of 600RPM when the injection time is more than 8.0ms, the pressure could reach more than 70 kPa (shown as table 1). The pressure of rail assembly is not allowed to more than 70kpa. An external damper could be added to the fuel rail to further minimize pulsations and to reduce the resonance frequency. Later SGMW B12 informed us they tested vehicle emissions with and without a damper and saw no difference so the external damper is not added.
Between 2000 and 3000 RPM, the pressure pulsation results showed a significant change in the magnitude (72.48 kPa, shown as table 1). Pulsations were relatively high at the 2000 RPM, 7.0ms test point, Port to port flow distribution was measured at 2000 RPM and 7ms (shown as figure 4) furtherly, it is in an attempt to simulate the part load condition A/F distribution issue seen in Injector2 at the table 2.

![Figure 4. Pulsation Measurement at 2000 RPM, 7.0ms](image)

Table 2. Flow Distribution Results at 2000 RPM, 7.0ms.

|        | Inj 1 | Inj 2 | Inj 3 | Inj 4 |
|--------|-------|-------|-------|-------|
| Pos 1  | 13.07 | 12.82 | 13.05 | 12.97 |
| Pos 2  | 13.00 | 13.06 | 12.85 | 13.06 |
| Pos 3  | 13.06 | 12.90 | 13.07 | 12.82 |
| Pos 4  | 12.80 | 13.05 | 12.98 | 13.06 |
| Rail Avg | 12.98 | 12.96 | 12.99 | 12.98 |

Dev. from rail avg. 0.05% -0.14% 0.08% 0.01%

Above 3000 RPM the pulsations generally remained below 30 kPa (shown as table 1). Such a change in performance could lead to difficulties in accurately mapping fuel flow over the speed range.

However, the pressure wave was synchronized with the injector2 firing which led to a repeatable result (Table 3), the pressure is no higher than 70kPa.

In this bench test, the variation from port to port was less than 1% according to S1190, the bench pressure pulsation test is passed.

![Table 3. Flow Distribution Results](image)
4. Recommendations on vehicle test

The resonance of the rail was measured at 45 Hz, which translates to 1350 RPM on a four-cylinder engine (Figure 5). Generally, it is best design practice to keep the resonance point outside the normal engine operating range.

![Figure 5. Resonance Test Result](image)

The injector flow rate used for this testing was 1.8 g/s on the bench test. Based on SGMW B12 vehicle test, an injector with a flow rate of 1.5 g/s would be sufficient. The vehicle test shows that reducing the flow rate from 1.8 g/s to 1.5 g/s would further improve pulsation performance.

References
[1] Ford specifications T687FL-10,
[2] Ford specifications T687O-034,
[3] Ford specifications T687O-035
[4] Continental specifications S1190-17
[5] SGMW specifications GMDAT-10