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Reliable Fuel Lines Design Considerations And Validation In A Passenger Car

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ABSTRACT

This paper is extension of the paper "Investigation and Damping a Moan Noise in a Passenger Car" where we discussed about the modifications in the fuel return hose for damping a moan noise by using an expansion chamber (35cc) between the fuel return lines. In this paper, we are going to discuss in a short overview of fuel system and the best design practices to be followed while designing reliable fuel lines in a passenger car. The fuel lines in a passenger car are divided into the high and low pressure circuit.

The best design practices will include the minimum sizes of fuel line, fuel line connection assembly, clearance study with the surrounding parts at high temperature surfaces, engine roll evaluation study and fuel line location within the vehicle envelope. This paper will also cover NVH design strategy and minimum validation requirement for fuel lines.

Keywords -Fuel Lines, Design Practice and Validation

I. INTRODUCTION

The function of the fuel system is to store and supply fuel to the cylinder chamber where it can be mixed with air, vaporized, and burned to produce energy. The fuel, which can be either gasoline or diesel, is stored in a fuel tank. [10]

A fuel pump draws the fuel from the Tank through fuel lines and delivers it through a Fuel to either a carburetor or fuel injector, then delivered to the cylinder chamber for combustion. Refer Figure 1 and Figure 2

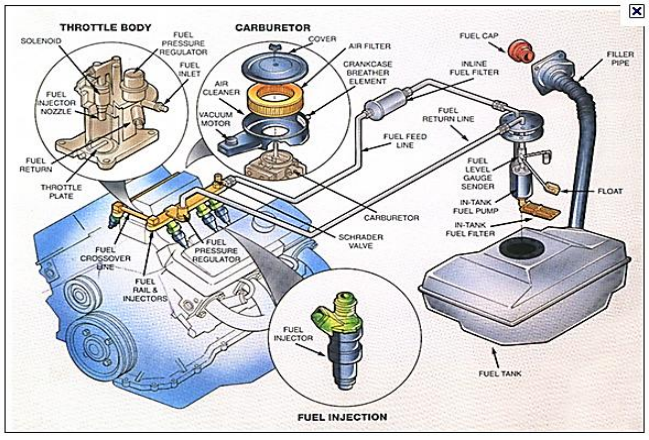

Figure 1. Fuel System Layout

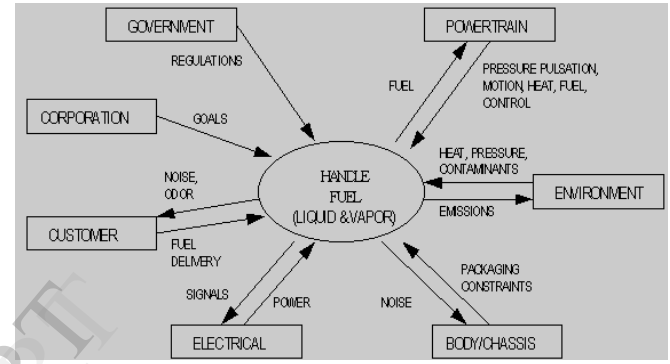

Figure 2. Fuel System Function Matrix

Fuel Lines- There are three types of diesel fuel lines. These include heavy weight lines for very high pressure between the injection pump and the nozzles, medium weight lines for light or medium fuel pressures between the tank and injection pump, and light weight lines where there is little or no pressure/return line [11].

- Low Pressure Supply
- High Pressure Delivery
- Fuel leak back and return

Refer Figure 3 for Fuel System Circuit

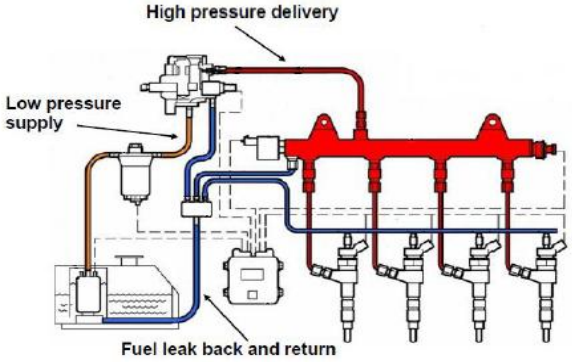

Figure 3. Fuel System Circuit

The fuel lines made from and fitting types are

- Nylon/Metal (galvanized steel or aluminum) or Reinforced rubber. Designer should try to minimize the amount of rubber line used, because rubber deteriorates over the time, but some rubber lines must be used to allow the engine to flex on its' mounts.

- Pipe Thread, Inverted Flare, Hose clamp and Captured O ring or Gasket. Refer Figure 3

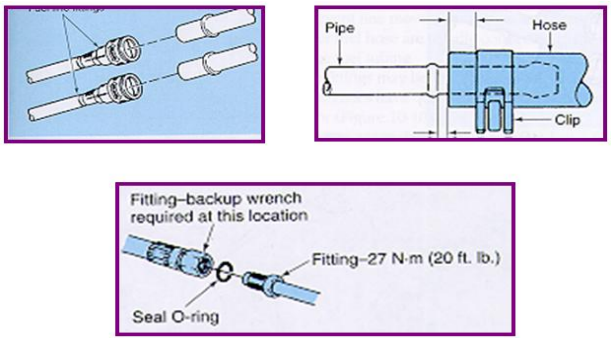

Figure 4. Fuel Lines End Fitting

II. DESIGN CONSIDERATIONS

✓ Fuel hose assemblies Rubber and Plastic:
Flexible rubber and plastic (nylon) fuel hose assemblies are comprised of a multi-layer tube with metal or plastic connections at both ends. Inner tube materials must withstand a variety of fuel compositions and stresses. Intermediate layers enhance inner tube burst pressure strength and assist in preventing damage from external sources. The exterior cover material provides added strength and protection against a myriad of harsh environmental factors such as temperature extremes, engine fluids, road debris, etc.
It is essential that preferred materials be selected for fuel lines and connector assemblies and those are thoroughly validated. Refer Figure 4

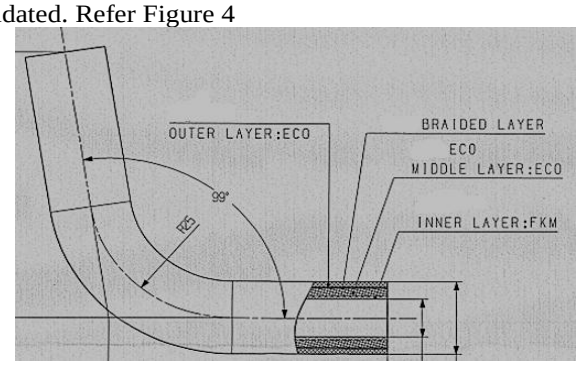

Figure 4 Fuel Hose Construction

✓ Reliable fuel line connections at assembly:
Design considerations-Fuel line quick connectors must be fully inserted or fixed at assembly. The clearance or the distance from the outside of the quick connector body to nearby objects ,measured radially, normal to the centerline of the connector body should be more than 30 mm for 360 degrees. There are different sizes of quick connectors; it should be selected according to the fuel line diameters.
If quick connectors are not assembled properly, then it can come out from the fuel line during use. This result would be fuel spillage and a possible fire in the vehicle.

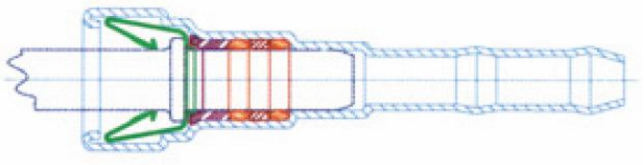

Figure 5 Quick Connector

✓ Engine roll evaluation for flexible fuel line:
This exercise defines the need for an engine roll study, and considerations for engine roll relative to fuel line routing. As engine rolls due to torque, the flexible fuel lines bridging the area will either be extended or compressed. As engine roll analysis is typically performed during the design phase of the vehicle. This analysis should be included in the process of designing the fuel lines, to ensure that the flexible can accommodate the roll. Three issues should be considered during fuel line design. The engine can roll in X or Y direction (in vehicle co-ordinate system) during ignition key turned on. This X or Y direction engine movement should be considered while designing the fuel lines.
First, the flexible section of the fuel lines should incorporate sufficient slack in the line to accommodate the roll. This practice would prevent the line assembly (connectors and materials) from being overstressed during the normal operation.
Second, the flexible fuel line articulation should be considered to ensure that an interference condition does not occur with adjacent components or subsystems. This portion of the study is necessary to ensure that damage does not occur to the fuel lines, e.g. that sufficient clearance exists for articulation.
Last, if connector devices (e.g. quick connects, etc.) reside in the area where articulation may occur, the articulation should not result in rotational cycling about its connection access. Fuel line connectors typically used are not designed for rotational cycling, nor validated for such usage. If an articulation study identifies a rotational cycling condition, specialized connectors may be necessary, or the system designed with pigtails or loops to avoid the rotational cycling.

✓ Placement of the fuel lines on vehicle:
This best exercise defines design considerations for the location of the fuel lines within the vehicle envelope. The fuel lines are placed in two parts underbody and engine compartment of the vehicle. Measuring fuel system integrity during high energy crashes is the principle consideration. The fuel lines should avoid the regions designed to crush for either front or rear or side impacts whenever possible. This generally implies routing the lines along the major fore-aft structural members for most of the way, but avoiding mounting to those structural members at the regions that they are designed to provide energy absorption through crush. When routing through a crush area is unavoidable,

consider shielding to decrease the likelihood of fuel line compromise. Since the engine/powertrain moves on its mounts and the fuel tank is either chassis or body mounted, a flexible portion of the fuel lines is implied, at least where the lines pass from the chassis to the powertrain.
By observing the powertrains roll axis on its mounts, the fuel lines can be designed to minimize the relative motion across that flexible portion. Routing the fuel lines close to the roll axis will reduce the linear displacement between the powertrain and chassis ends of the fuel lines. Minimum relative motion adds robustness to a design. The flexible portion of the fuel lines must be routed to allow enough slack to prevent severe tension during a crash event. This implies an understanding of the relative motion of the powertrain to the chassis during the crash. The flexible portion of the fuel lines are more vulnerable to pinching and slicing than are the metal connecting pipes. There can be no sharp edges and/or bolt points oriented towards the flex portion of the fuel lines, either in their installed or crash displaced positions. As a general rule, the fuel lines (both rigid and flexible portions) should avoid crush zone pinch points.

- ✓ Fuel line clearance study with high temperatures surrounding parts in the vehicle:
  This best exercise recommends the clearance between fuel system lines and high temperature parts such as exhaust system components. The best practice recommends corrective action if this clearance cannot be maintained. The clearance from high temperature parts prevents hose degradation due to over-temperature condition and also prevents perforation and loss of fuel. The clearance is defined in the dynamic state. This represents the minimum distance associated with engine roll, rapid braking, rapid acceleration, or other short lived, high movement events. If temperatures exceed their limits, thermal protection, such as a protective sleeve or a heat shield between the exhaust system components and flexible hose, should be provided.

- ✓ NVH design strategy for fuel lines:
  Clearance
  Buzz, Squeak, Rattle recommends fuel lines (individual or bundled) should have a minimum 5mm clearance to the body structure, a minimum 15 mm clearance to the stationary components and a minimum 25 clearance to any moving part. Do not pinch items such as wiring between the fuel lines and body. This avoids transmitting fuel line hammer and fuel rush to the body.

- ✓ Fuel pipe diameter in standard size:
  Fuel lines should be in minimum and optimum sizes for any kind of material either nylon, mild steel, aluminum or multilayer reinforced rubber. If fuel delivery line is very small, then it will affect on inadequate fuel supply to engine at wide open throttle. If fuel return line is too small, it results in excessive return fuel pressure.

- ✓ Part number labeling and color coding on fuel return line:
  This best exercise suggests ways to use color to aid the assembler in identifying plumbing combinations.

III. DESIGN VALIDATION TESTS

The design validation stage will cover the component level testing of the fuel return line to predict the life of fuel return line. The design validation covers qualification tests for rubber fuel system assemblies with quick connector assemblies intended for use in conducting liquid fuels or fuel vapour. These hose assemblies are suitable for use at temperatures of 40 to 150°c (continuous), -40 to 160° (excursion) and operating pressures to 10 bar (1000Kpa). In design validation stage, fuel return line with an expansion chamber validated for different tests to meet the part in terms of durability and vehicle environment condition.

The following tests are proposed for a component level testing on Fuel Return Line with 35cc Expansion Chamber and these tests are carried out at the supplier end and passed in all tests. Refer Table 1.

Table 1. Fuel Line Minimum Validation Plan

Validation Requirement			
Sample Size	**Item**	**Requirement**	**Observation**
1-5	Leakage Test	≥ 10 bar (1000 Kpa)	Passed
1-5	Internal Cleanliness	Impurities < 0.15 g/m for Metal and Non Metal Particles	Passed
1-5	Burst Test	≥ 31 bar (3100 Kpa)	Passed
1-5	Pressure cycle test	150000 cycles at 10 bar. No Pressure Drop and No leakage	Passed
1-5	Pull off load for Quick Connector	≥ 147 N (14.7 Kg)	Passed

IV. CONCLUSION

The fuel lines are the safety components in the vehicles, so it should meet to the safety related regulations. The designer should take care of all the following points while designing the reliable fuel lines and minimum validation at the component level.

- Fuel line material
- Clearance study
- Engine roll movement
- Connector/End fitting selection
- NVH criteria

The Fuel return line with 35 cc of expansion chamber is passed for all validation tests mentioned in above chart.

REFERENCES

1. Deepak Rana and Amit "Reduction of Fuel Delivery System Noise in a Passenger Car Using EBD Approach" SAE 2011-26-0071,DOI: 10.4271/2011-26-0071
2. Randell P. Izydorek and G. E. Maroney "A Standard Method for Measuring Fuels System Pulse Damper Attenuation"SAE2000-01-1086, DOI: 10.4271/2000-01-1086
3. Kazuteru Mizuno, Shoichiro Usui, Izumi Imura,Tetsuo Ogata,Hikari Tsuchiya "Fuel Rail with Integrated Damping Effect" SAE-2002-01-0853,DOI: 10.4271/2002-01-0853
4. A Selamet and Z. L Ji "Acoustic Attenuation Performance of Circular Expansion Chambers with Extended Inlet and Outlet" Journal of Sound and Vibration (1999) 223(2), 197-212
5. Nicholas Earnhart, Kenneth Marek and Kenneth Cunefare "Novel,Compact Devices for Reducing Fluid-Borne Noise" SAE 2011-01-1533, DOI: 10.4271/2011-01-1533
6. Kalevi Huhtala and Matti Vilenius "Study of a Common Rail Fuel Injection System" SAE 2001-01-3184, DOI: 10.4271/2001-01-3184
7. Kazutaka Oshishi and Tamitoshi Maeda " The New Common Rail Fuel System for the Duramax 6600 V8 Diesel Engine" SAE 2001-01-2704, DOI: 10.4271/2001-01-2704
8. Piyush Kende,Anand Kulkarni,Uday Kothalikar and Vivek Lakhera "Simple,Effective and Low Cost Solution for Power Steering Hydraulic Rattle Noise Isolation" SAE 2006-01-0936, DOI: 10.4271/2006-01-0936
9. Manasi P. Joshi, E Ramachandran and N.V.Karanth "Noise & Vibration Measurement Techniques in Automotive NVH" AdMet 2012 Paper No.VN 003
10. Wellignton and Alan Asmus "Diesel Engines and Fuel Systems" 4th Edition
11. Tony Kitchen "Common Rail Diesel Fuel Systems" AK Training Material
12. www.sciencedirect.com