

Road Simulation Bench as a Tool to Reproduce the Real Life Ageing of the Exhaust System

A Case Study: The Flexible Ageing

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ABSTRACT

Through a case history, we report a procedure to age exhaust flexibles on a Road Simulation Bench, in order to reproduce the acoustic failures occurred during vehicle ageing. The bench ageing has been the key instrument to solve an acoustic problem (a ring) observed on the vehicle after ageing. It is shown that it was mainly due to the partial loosening of the external outer braid (which caused the flapping of the outer braid against the bellows).

INTRODUCTION

The exhaust system is generally described as composed by two sections: the hot end, i.e. all the components between the manifold and the decoupler, mainly devoted to the emission after-treatment and located in the engine hood, and the cold end, i.e. from the decoupler to the tailpipe, mainly devoted to noise attenuation and located underfloor (even if it is quite common to find exhaust after-treatment devices also underfloor). The decoupler presence (generally a flexible) is necessary due to the fact that the hot end is stressed mainly by engine vibrations, while the cold end by road vibrations [1,2].

In order to introduce the following discussion, it can be useful to give a short reminder of the flexible structure and of its functions in the exhaust line.

A standard flexible is generally composed of three concentric elements:

- i) an external braid, for mechanical protection of the bellows and for vibration damping;
- ii) a metallic bellows, which have the function to achieve the functional requirements of optimised flexibility, fatigue life and prevention of gas leakages;

- iii) an internal liner, made of interconnected rings. This structure guarantees mechanical resistance, still preserving flexibility in X, Y and Z axes. Beside this function, the liner presence prevents noise problems arising from the interaction of the gas flow and the bellows, contributes to reduce gas thermal losses (which should be minimised if a catalyst is present downstream) and acts as vibration damping.

The main function of the flexible is to absorb the vibrations which come from the engine so that they are not transmitted to the cold end, and to absorb the vibrations which come from the road through the cold end so that they are not transmitted to the hot end. Other functions are the absorption of the thermal expansion of hot and cold end and the compensation of possible misalignments of the exhaust converter.

Due to the fact that during vehicle life the exhaust system is thermally and vibrationally stressed, its design and validation includes reliability and fatigue tests on the separate components and on the whole system. Among the tests made on the whole system, the most complete is of course the vehicle life test, where the more stressing events of the vehicle life are reproduced on the road for the proper time. This test is very expensive and it should be performed only on the already optimised solution. The validation of alternative test procedures able to reproduce real life ageing is mandatory for R&D testing laboratories.

Another important aspect is that the particular ageing test procedure must be customised on the specific component/part of the line, to be fully validated. For example, thermo-mechanical reliability of the hot end can be finely reproduced at the engine bench, in particular for the reliability of the manifold, of the canning and of engine brackets. Unfortunately this is not true for the flexible, due to the fact that standard engine benches do not reproduce all the stresses suffered by the flexible

(vide infra). So the reliability testing of a component like the flexible is not trivial, because in reality it is stressed both by the cold end road induced vibrations and by the hot end engine induced modes. In particular, it receives five different kinds of stresses during its life:

- a) engine combustion vibrations (which depend from the combustion events and are characterised by high frequencies and low displacements);
- b) the vibrations modes of the engine itself, like the rocking modes of the engine (which are activated for example by the gear change; these phenomenons are characterised by low frequencies and high displacements);
- c) road induced vibrations (low frequency, high displacements);
- d) inertial movements of the cold end (for example during braking, due to the fact that it is suspended with elastic rubbers) ;
- e) high temperature and thermal gradients.

The best flexible ageing procedure should simulate all these stresses at the same time; moreover, not all the stresses contribute with the same strength.

Standard exhaust testing tools are generally not able to reproduce all the mentioned stresses. For example, the main limit of standard engine benches is that they stress the exhaust system by engine combustion vibrations and high temperatures, but they cannot reproduce the vibrations modes of the engine itself, the road induced vibrations and the inertial movements of the cold end.

Another very used testing tool, i.e. the burner/vibrating bench, can of course reproduce thermal events, but it is not able give the complete gamma of vibrational stresses. In particular, it is our experience that the ageing of the single component on a burner bench, able to give periodical thermal stresses and deformation along the x-z axes, gives good results for the comparative test on different flexibles when strong mechanics failures have to be reproduced, but – to our knowledge- it is not known a real well documented procedure able to reproduce on-vehicle ageing of the flexible, in particular with correlations with on road results and the ability also to reproduce flexible failures generating acoustic problems.

One of the testing tool which in our opinion is better simulating the road flexible ageing is the Road Simulation Bench, i.e. a testing device where thermal and vibrational stresses measured from the fields are reproduced (Fig. 1,2). Thermal stresses are reproduced by means of a burner, while engine and road vibrations are reproduced through hydraulic jacks. This tool is a powerful tool in order to simulate the ageing of the whole exhaust system; however, for sake of brevity, this contribution is focalised on the description of the ageing of the flexible, in particular for the acoustic failures which happen in absence of visible mechanical breaking of the component.

MAIN SECTION

THE LAB AGEING FACILITY

The Road Simulation Bench is a facility including a burner to give thermal stress and a hydraulic unit to generate the vibrational stresses.

The CNG burner has a maximum exhaust gas flow of 600 kg/h and can reach the maximum air temperature of 1100 °C. The hydraulic unit is composed of rear vertical, front vertical and engine torque jacks able to reproduce along the exhaust line the frequencies, the forces, the displacements and the accelerations measured on the vehicle.

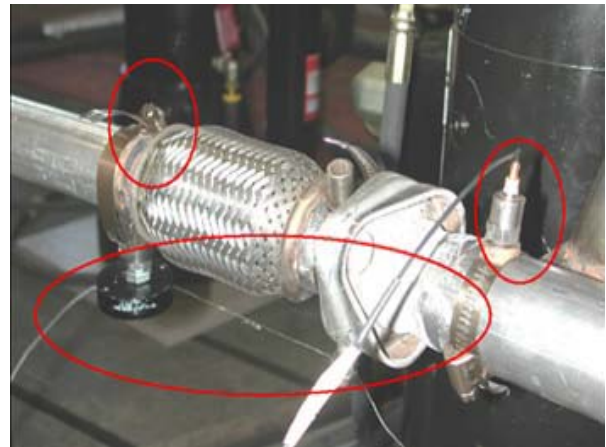


Fig. 2: Picture of the tested flexible. The positions of the accelerometers and the wire transducers are shown.



Fig. 1: Picture of the Road Simulation bench.