Mechanical Assessment of Fuel Line Hoses under Variable Pressure

RAMONA NAGY*, REMUS STEFAN MARUTA, MIHAI HLUSCU, KAROLY MENYHARDT
Politehnica University Timisoara, 2 Victoriei Sq., 300002, Timisoara, Romania

The automotive industry is one of the largest consumer of flexible hoses for fluids such as fuel or cooling. In order to limit the post production costs, every aspect of a vehicle must be tested in advance, including the lifespan, durability or failure of hoses. Throughout this paper summary results are presented for 4 types of fuel line hoses tested under controlled displacement loads at various pressures in order to validate the Finite Element Method simulations.

Keywords: hose, PVC, neoprene, pressure

The XX-th century provided proof regarding the necessity of transportation and although rail vehicles offer an environmentally aware way, combustion engine vehicles are the most widely used means of locomotion. In the last 20 years major steps were taken toward electrical alternatives, but to this day worldwide there is a ratio of around 1:250 in favor of internal combustion engines. So, most vehicle encounter a fuel-line-related issues. Because of ethanol's effects on rubber, plastic and metals [1-3], there is a struggle in finding a solution that can offer a reliable delivery systems able to handle fuel in different mechanical conditions [4].

The classic fuel line hoses were made out of rubber with or without reinforcement [5-8].

Rubber's ability to withstand very large strains without permanent deformation or fracture makes it suitable for this task. Neoprene fuel hoses or PVC are also offering a reliable alternative that can better handle the corrosive nature of the fuel. This application imposes large static and time-varying strains over a long time [9]. To address the issue effectively and economically, engineers need to model and design for mechanical behavior early in the product development process. This need was partially addressed by the development of simulation software capable of predicting stress and strain histories but, real life input and output values are crucial for the relevance of the simulation [10-12].

Experimental part

Testing and results

In order to assess the mechanical behavior of such hoses with Finite Element Method (FEM) software, 4 types of hoses were subjected to cyclic buckling under various pressure loadings**,** **(**fig.1). These tests were accomplished in order to validate the FEM models.

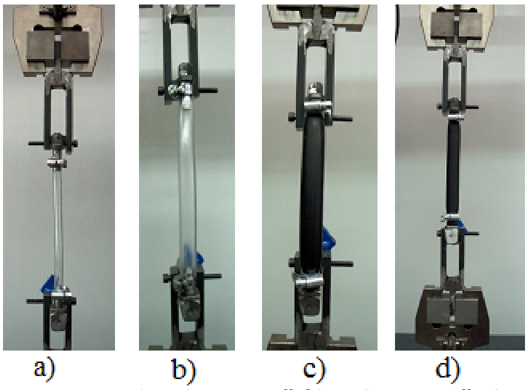

Fig.1 Hose types: a) PVC 1mm wall, b) PVC 2mm wall, c) rubber, d) neoprene

The hoses were mounted as in figure 2 and external pressure was provided from a detachable high pressure compressor. The tested hose (2) is clamped into freely revolvable fixtures (1). Through an air tight seal air is pumped into the hose until de required pressure is obtained. After the valve are secured and pressure is confirmed, the hose is disconnected from the compressor and cyclic bucling is performed by moving the upper fixture vertically.

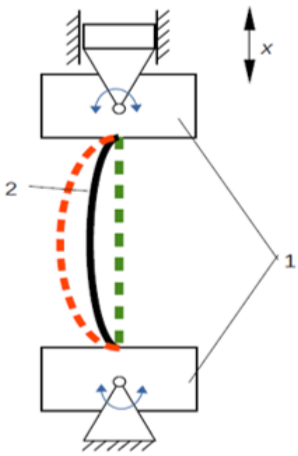

Fig. 2 Testing setup

The required force to perform a 120 mm displacement of the fixture is measured with the aid of a HBM U9C 1kN force sensor and recorded as force-displacement curve. Vertical displacement is performed with a velocity of 200 mm/min.

For each type of hose, a minimum of 3 items were tested, but usually this was 6 in order to attain a converging curve that can be considered as representative for the entire population (fig.3). Hoses were fitted in a un-tensioned initial position.

The first type of PVC hoses had a thin wall of 1 mm and were rated at maximum of 3 bars so the tested pressure was at this value. Above 4 bars ireverssible swelling of the hoses occurred so further testing was not done to observe its ressistnace.

The second type of PVC hose had a 2 mm thick wall (fig.4) and handled without significant deformation pressures up to 12 bars. Both PVC hoses had no reinforcement mesh.

For every sample the necessary force to complete the buckling is always lowest at the first run (fig.5 R1), the second and third runs (R2-R3) needing a higher force to attain the same displacement. The fourth, fifth or sixth runs maintain this level or drop to the first run levels.

* email: ramona.nagy@upt.ro

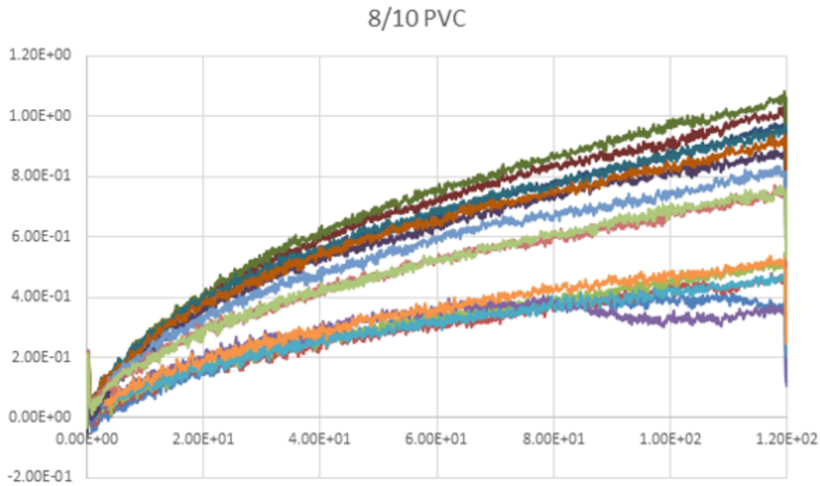

Fig.3 PVC hose inner diameter (ID) 8 mm, outer diameter (OD) 10 mm at 3 bar

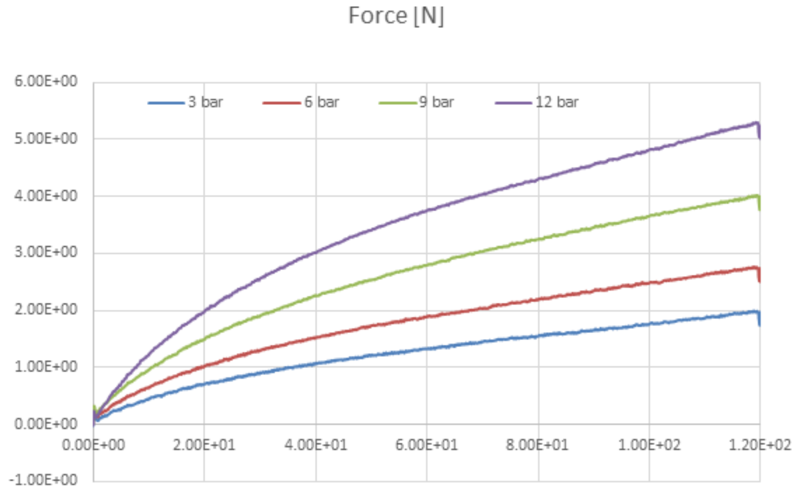

Fig. 4 Opposing forces at set pressures ID8 OD12

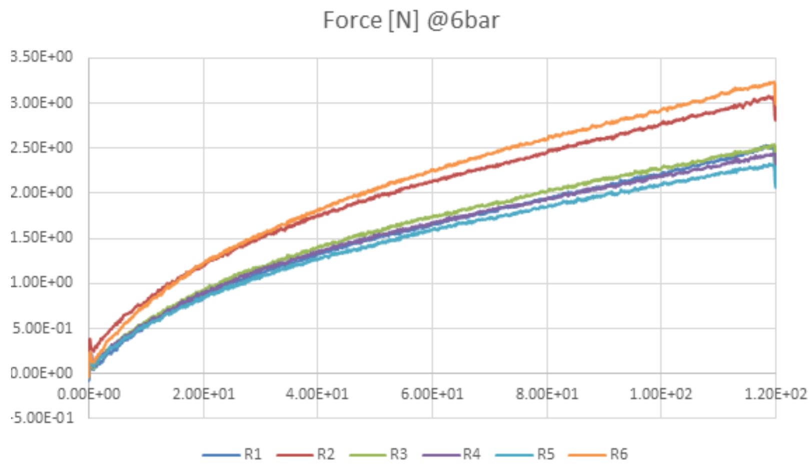

Fig. 5 Force needed for buckling PVC ID 8 OD12

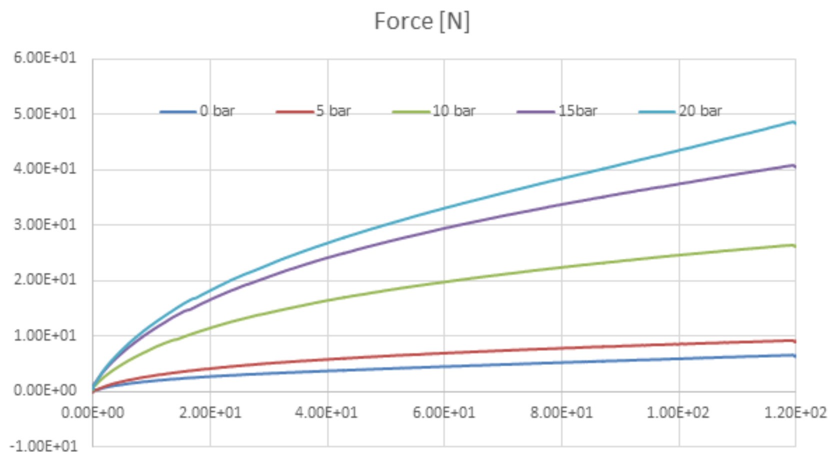

Fig. 6 General purpose rubber hose

Pressure [bar]	Initial length [mm]	Final length [mm]	Initial OD [mm]	Final OD [mm]	Max force [N]
0	200	200	14.5	14.5	0.5
5		184		15.3	0.9
10		171		17.5	2.7
15		163		20.2	4.1
20		163		24	4.8

Table 1
LENGTH-OD VARIATION

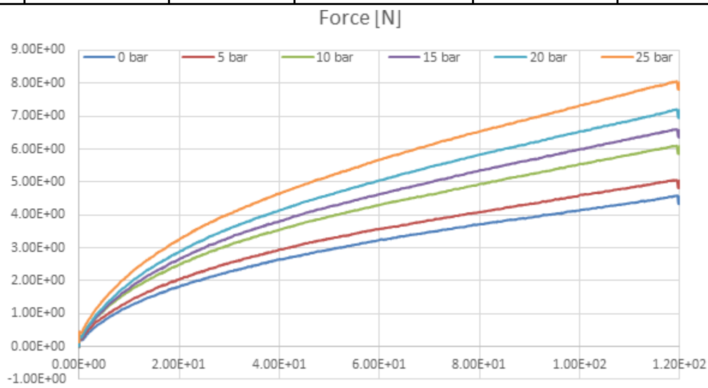

Fig.7 Neoprene hose ID8/OD14.5

The second main type of hoses were textile reinforced. During our test a general purpose synthetic elastomer rubber hose was used and a 10 bar high tensile textile cord reinforced polychloroprene (neoprene) hose.

Results and discussions

Although the purpose fuel line rubber hose had a textile reinforcement it presented an unusual swelling that can be observed in table 1.

In the case of the high tensile textile cord reinforced polychloroprene hose rated at 10 bar there was no visible increase in diameter proportional with the pressure load, even if the pressure was increased at 25 bar (fig.7).

The development of an accepted test configuration: kinematics of the grips, predictable deformation of the hoses and keeping an initially set internal pressure throughout the entire test was a difficult and challenging task that underwent several modifications until a final solution was found.

Throughout the paper 4 common types of fuel line hoses are presented with their response to force in various pressure loads. Two of the hoses are made out of fuel resistant PVC having an inside diameter (ID) of 8 mm and wall thickness of 1mm, respectively 2 mm with no reinforcement. Without fuel/pressure both of these hoses can buckle under their own weight so added pressure was needed in order to avoid self-kinking. Using pressures above 3 bar swells the hoses and permanently deforms them.

The general purpose synthetic elastomer rubber hoses although reinforced with textile cords started swelling proportionally with the applied pressure, but shrunk back to almost original dimensions once pressure was relieved.

The 10 bar high tensile textile cord reinforced polychloroprene hose acted normally throughout the entire testing process. Although rated at 10 bar it performed as expected even at 25 bar, without any visible deformation.

One interesting common characteristic was that, in all the tested hoses - reinforced or not, always the second and third run yielded a higher required force for the same buckling as in the case of the first or latter runs, no matter what pressure was applied. This temporary stiffening of the material is a phenomenon that must be further studied..

Conclusions

The extended set of values recorded from the buckling tests will aid in defining a more realistic Finite Element Method analysis for these type of hoses. Even though these tests are simple in nature, because of the different behavior in simulation and real life testing, further analysis of these items are necessary until the two coincide.

As seen from simulations, multiple deformation factors acting together (overlapping), such as external force - responsible for buckling, internal forces -pressure from compressed fluid or even temperature variation - responsible for material stiffness, are not yet completely understood and sufficiently theoretically and numerically explained.

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Manuscrpt received: 14.03.2019