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Static and Dynamic Analysis of Plastic Fuel Tanks Used in Buses

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Abstract

In today's world the conventional metal fuel tanks used in buses are being replaced with plastic fuel tanks. In this paper, a part of the project which aims to develop a computer aided methodology for developing/designing of the plastic fuel tanks based on static and dynamic analysis is presented.

Coupon tests are conducted to acquire the mechanical properties of the plastic material. In the static analysis, equivalent static loads are applied to the fuel tanks. In the dynamic analysis, the time varying loading and the inertia of the fluid and fuel tanks are taken into account using modal transient analysis.

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1. Introduction

Plastic fuel tanks instead of steel tanks have been used in recent years due to their several advantageous properties such as their light weight, low material and production costs, high safety levels, greater capacity due to greater choice of shape, non-corrosiveness property and good design flexibility In 1972, VW Passat cars with plastic fuel tanks were manufactured for the first time as a mass production. Since then the major automobile manufacturers around the world have started to show interest in and to work on the use of the plastic fuel tanks [1].

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There exist many researches on the fuel tanks in the literature. Fuel permeation mechanism was defined and multilayer fuel tanks' structural features and the development of resins were discussed by Kurihara et al. [2]. The properties, advantages and disadvantages of high capacity plastic fuel tanks of trucks were investigated in [3]. Researchers found that, because of the high levels of sulfur in the content of fuel sold in Brazil, corrosion occurred inside the steel fuel tanks and, the fuel caused some damages to the engine injection system. After examining several alternative materials in terms of certain features such as cost, safety, recycling, replacement and compatibility, they came up with the solution that the fuel tanks should be manufactured using polyethylene material.

Life cycles of steel and plastic fuel tanks are compared by Stephens et al. [4]. In order to obey the federal standards and to enhance the fuel economy, usage of light components in automotive industry became a requirement. It is also important to manufacture components regarding the environmental concerns. The results show that, while material is being manufactured, solid waste generation is high for steel compared to the polyethylene (HDPE), but the energy consumption is higher in manufacturing process of the HDPE. In the usage phase, it is desirable that the energy consumption level is lower. In fact, considering the environmental conditions, HDPE is more advantageous than steel. Considering the production stage, it is observed that the HDPE is more environment-friendly compared to the steel. However, at the end of the lifecycle, steel seems to be more sensitive to the environment because of the disadvantage of the plastic material that it is not recyclable. To be able to get rid of this disadvantageous situation, some researchers have conducted research on recyclability of these plastic materials. In one of these studies, HDPE fuel tanks that consist of 27% recycled material were manufactured. Those recycled materials were obtained from the fuel tanks of vehicles that had already completed their life cycles [5].

The effect of sloshing in a fuel tank is one of the most crucial problems for the fuel tank design, and, obviously, percentage of fullness influences sloshing effects. The sloshing in a partially full tank in the state of failure was investigated by Vytla et al [6]. In this study, there are two tanks filled up to 53 % and 40 %, and two breaking events, a light one and a heavy one were investigated. The sloshing problem was solved by the fluid-solid interaction technique. Water is used instead of fuel. It is found that the sloshing level increases in the case of low percentage of fullness. In other words, it takes time for a liquid to become calm and there is a high probability of fuel noise while the water percentage is lower. In another study, the fuel in a tank was modeled. After three fullness rates of 51 L, 42 L and 28 L were compared to each other, the 42 L of fuel fullness were found to cause the highest noise [7].

There are several methods to model the fluid in fuel tanks. One of them is the oscillation method which is used by Reis and Pala [8]. In this work, the effect on braking dynamics of the liquid behavior is examined. The LS-DYNA finite elements analyses program was used to solve the Fluid-Solid Interaction (FSI) problems by Vesenyak et al. [9]. Fluid sloshing problem was analyzed using the Lagrange, Euler, ALE and SPH formulations. Lagrange and ALE formulations were found as the best simulations when they were compared to the test results. Hence, it was also concluded that these two formulations could be used for automobile fuel tanks.

Modal analysis of transient liquid sloshing in partially full fuel tanks is presented by Zheng et al. [10]. In this study, the FLUENT program is employed for simulations. Cylindrical tanks are taken partially filled (40 %), and longitudinal accelerations between 0.1g and 0.4g were applied to the tanks. It is found, by analyzing temporary sloshing forces and liquid surfaces, that sloshing has a periodic oscillation. Then, the Fourier Transform is used to convert the sloshing forces from time domain to frequency domain. The spectrum analysis indicates that the fundamental oscillation which has greatest amplitude is the most significant oscillation for liquid sloshing.

Sloshing modes of the fluid in a rectangular tank subjected to horizontal harmonic motion are investigated by Virella et al. [11]. Both linear and nonlinear 2D finite elements are used. Natural sloshing periods and their modal pressure distribution are investigated using the ABAQUS program. Bulk response of the fluid is modeled using linear state equation and Newton's viscous shear model. The ABAQUS program suggests that the elastic bulk module should be two or three times smaller than the real value.

In this paper, a part of the project which aims to develop a computer aided methodology for developing/designing of the plastic fuel tanks based on static and dynamic analysis is presented. First, the mechanical properties of the plastic fuel tanks are obtained from the coupon tests by universal testing machines and then these properties are used in the finite element analysis. The finite element analyses are conducted in two stages. In the first stage, equivalent static loads of real dynamic loadings are applied to the fuel tanks. Maximum/minimum "g" forces are computed using the