Pulsation Attenuation Analysis of Double-Chamber Composite Hydraulic Suppressors with Inserted Conical Tubes

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A one-dimensional analytical approach is developed to predict the pulsation attenuation performance of double-chamber compound hydraulic suppressors. The theoretical insertion loss agreed well with experimental results. The need for broadband pressure pulsation attenuation has led to extensive research on the structure improvement. In the present work, the straight-through tube has been replaced by a conical tube and two improved hydraulic attenuator configurations are presented. A parametric study to investigate the effects of different parameters on the research frequencies is included as well. The validity of the models of the improved structures is demonstrated theoretically and experimentally.

1. INTRODUCTION

With the development of hydraulic systems towards higher pressure, vibration and noise have become an urgent problem to be solved. In addition, pressure pulsation is always considered as the main source of these issues. Although there are a number of approaches to attenuate it, installing hydraulic suppressors is considered to be one of the most effective and flexible ways. Currently, there are a variety of attenuators with complicated functions. They can be generally divided into active and passive types. On one hand, because of high design requirements, difficulties, the fact that it’s expensive to manufacture and poor reliability, active pressure pulsation attenuation mainly rests on laboratory research and development phase. On the other hand, passive hydraulic suppressors could be further classified into three forms, resonant type, expansion chamber and interference type. Given that other two forms’ disadvantages, inconvenient movement and bulk mass, expansion chamber types are flexible ways to avoid above problems. Thus, they are used more widely. Incidentally, there are many different kinds of theories and methods aimed at muffler design, for instance, the transfer matrix method, which is widely used for one-dimensional (1D) plane waves. In order to appreciate the limitations of this approach, it is imperative to consider general three-dimensional (3D) wave propagation in tubes. Therefore, a 3D analytical approach, the finite element method (FEM) and boundary element method (BEM) are proposed.

At the very beginning, two double-chamber compound hydraulic suppressors were proposed in this paper. In addition, a 1D analytical approach was developed to predict their pulsation attenuation performance. Then, the need for broadband pressure pulsation attenuation has led to extensive research on the improvement of the structure. Therefore, the straight-through tubes, which were used in these compound hydraulic suppressors, were replaced by conical tubes. After that, the validity of the models of the improved structures was demonstrated theoretically and experimentally. Finally, a parametric study to investigate the effects of different parameters on the research frequencies was also included.

2. THEORY OF MODELLING

Before the mathematical modelling, two assumptions should be put forward:

- In the ideal case of a rigid-walled tube with sufficiently small cross dimensions filled with a stationary ideal (non-viscous) fluid, small-amplitude waves travel as plane waves.
- The variation of pressure pulsation with time is harmonic.

When there was a pressure pulsation disturbance, the state variables in this paper were represented as,

\[ \tilde{p} = p_0 + p, \]  
\[ \tilde{u} = U_0 + u, \]  
\[ \tilde{\rho} = \rho_0 + \rho. \]

Currently, multi-chamber reactive gas silencers are widely used in medium and high power diesel engines, besides, good middle and low frequency noise elimination effect can be obtained. Thanks to the inspiration from the successful application of these structures in mufflers, two double-chamber compound hydraulic suppressor configurations were put forward in this paper.

Based on the above hypothesis, the Helmholtz equation was obtained,

\[ \nabla^2 p(x, y, z) + k^2 p(x, y, z) = 0; \]

\[ p(x, t) = Ae^{j(\omega t - kx)} + Be^{j(\omega t + kx)}. \]