COMPUTATIONAL SIMULATION OF A PNEUMATIC CHIPPING HAMMER

Rahul Kadam, Kyle Schwartz, Marty Johnson, Ricardo Burdisso
Vibration and Acoustics Labs, Virginia Tech, Blacksburg, Virginia, U.S.A.

Introduction

Occupational exposure to hand transmitted vibration (HTV) arises from the hand held powered tools extensively used in the mining and construction industry such as rock drills, chipping hammers, chain saws etc. Regular exposure to HTV is the major cause of a range of permanent injuries to human hands and arms which are commonly referred to as hand-arm vibration syndrome (HAVS). In addition to this, the percussive tools generate overall sound power levels in excess of 110dBA in most cases. Such a high sound power level greatly exceeds the maximum permissible exposure limit (PEL) of organizations such as National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA). Long term occupational exposure to this noise has been diagnosed as the main reason for permanent hearing loss in the operators. It is therefore important to develop an understanding of the mechanisms which lead to these high vibration and sound levels and in order to do this a detailed computational model of a pneumatic chipping hammer has been made.

This paper presents a nonlinear computational model of a pneumatic chipping hammer. In order to better understand the dynamics of the chipping hammer, the hammer was subdivided into components that are shown in figure 1 (a) (based on a chipping hammer manufactured by Atlas-Copco). The hammer mainly consisted of a center body, a moving piston and a chisel. Compressed air is used to drive the piston inside of a cylinder and on the downward stroke this piston impacts the chisel to create the hammer effect. The machine has one pneumatic valve and this valve regulates the air supply either to the upper chamber or to the lower chamber. The valve changes according to the relative pressures in the two chambers and the supply pressure. There are also twelve different exhaust ports at two positions along the cylinder labeled upper ports and lower ports. As the piston moves the ports can be closed or open (allowing exhaust).

Fundamentally, the computational model was made up of two different sub-models, a fluid model and a structural dynamic model as shown in Figure 3 (a) and (b) respectively. The first sub-model takes into consideration the fluid dynamics of the machine since the hammer is driven by compressed air. Equations for the mass flow rate though bleed orifices (assuming an isentropic process) [1] is used to determine the mass flow into and out of the upper and lower chambers. From this the pressures in the two chambers and consequently the forcing on the piston can be calculated. The second sub-model deals with modeling the structural

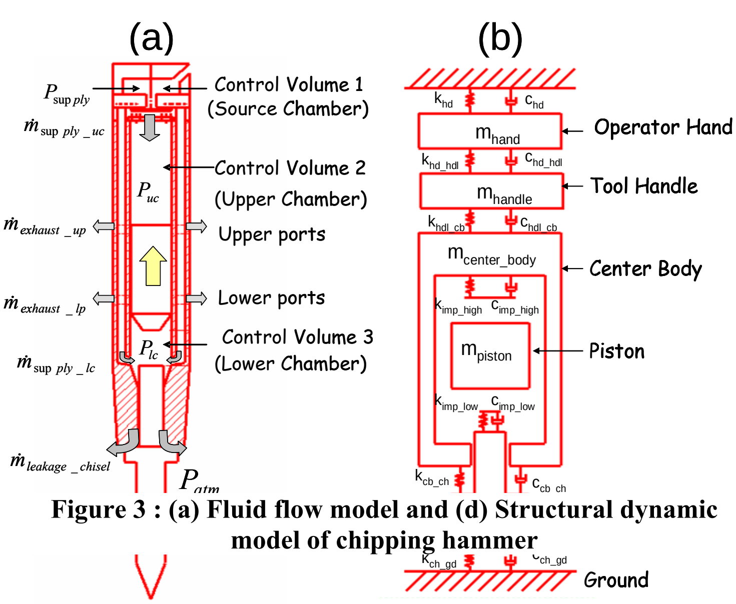

Figure 3 : (a) Fluid flow model and (d) Structural dynamic model of chipping hammer

components of the chipping hammer. The structural model consists of various lumped masses[2], each representing a specific component of the chipping hammer as well as the ground and operator's hand. The impact dynamics were also incorporated by connecting the piston and the chisel with a non-linear spring. The fluid flow and structural models were then coupled together using a time domain, state space formulation to compute the displacements of each component, the pressures in the chambers, the impact forces and the jet velocities from the exhaust ports. The computational model was then validated using experimental obtained vibration levels and exhaust velocities.

Results

Figure 4 (a) and (b) show the experimental and computational exhaust velocities from the upper and lower exhaust ports respectively. There is a very good match between the exhaust jet velocities measured during lab tests and the exhaust jet velocities calculated from the computational model. Also the tool impact frequency measured from lab tests is approximately 27 Hz which is very close to the tool impact frequency calculated from the computational model (32Hz). Keeping in mind the nonlinear nature of the fluid flow model, these can be considered as good results. However, further refinement of the fluid flow model will be continued in the near future. The structural dynamic response of the computational model will be discussed at the time of presentation.

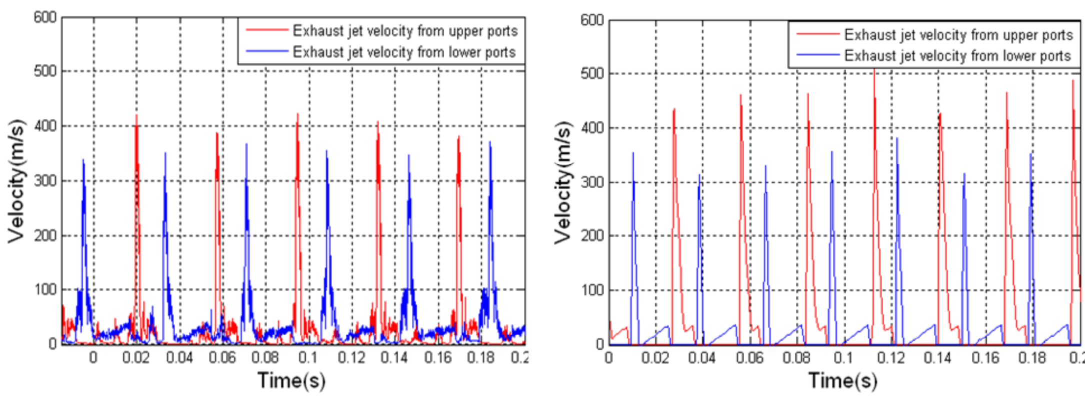

Figure 4 : Exhaust jet velocities (a) experimental results, (b) computational results

This model provides a unique opportunity to evaluate different vibration and noise control techniques and consequently to help determine the best possible control method. The model would avoid the need for extensive laboratory testing which is time consuming as well as expensive.

References

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