Experimental Characterization of the Noise Generation Mechanism of Percussion Drill Steel Rods under Laboratory Controlled Conditions

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1 Introduction

Percussion drills are the source of the most serious noise problems in mining activities, because of their extremely high noise levels and widespread use [1]. The exhaust air is the primary noise source on pneumatic rock drills. Manufacturers now offer mufflers that can reduce the exhaust noise at a level at which the drill rod vibrations become the dominant noise source [2]. The noise levels remain high, future efforts should concentrate on reducing the drill rod noise.

Works by Hawkes *et al.* [2, 3] for the U. S. Bureau of Mines provide the most complete description on the noise and vibration of percussion drill rods. The two most important types of elastic waves generated in drill rods are longitudinal and bending waves. Only the longitudinal waves make contribution to the drilling rate. The bending waves are caused by non-centralized impacts, drill rod curvature and non-uniform bit/rock interface. Drill rod noise is generated by Poisson's ratio expansions and contractions of the rod as the longitudinal waves travel up and down it and by transverse rod motions induced by bending waves. The radiation efficiency is much higher for bending waves than for longitudinal waves. As expected, most of the impact energy is transformed into longitudinal waves. It is generally assumed that flexural waves are the main noise source on drill rods. However, measurements up to now have been somewhat contradictory and researchers are still unable to state with certainty that this is indeed the case [4].

In this paper, the relative contribution of longitudinal and flexural waves is investigated experimentally on a laboratory test fixture designed to simulate a percussion drill.

2 Test fixture and procedure

The test fixture (figure 1) was built around a 2.44 m long rod. The outer and inner diameters were respectively 38 mm and 14 mm. The lower end of the rod was equipped with a bit in contact with a concrete block. The 10.5 kg hammer was accelerated by a spring under compression over a 8 cm course. The spring was compressed by pulling a cable attached to the hammer. A clamping system was used to hold the hammer in its armed position. The system allowed to be rapidly released with very few moving parts. The rod was guided at its upper extremity to avoid a random impact point. A fork lift was used to thrust the rod with a static load of 7 000 N, this load is representative of percussion drills in operating conditions. To avoid acoustic perturbation by the contact noise between the hammer and the rod, an enclosure was mounted around the hammer system. The drilling bit was also enclosed.

The rod was instrumented with four full bridge strain gauges transducers, two of them measuring longitudinal waves and the two others measuring flexural waves. To be sensitive to longitudinal waves, strain gauges were mounted on opposite sides of the rod and coupled in series. To measure bending waves, the gauges were again mounted on opposite sides and connected to the bridge to estimate the strain difference between the two sides. Full bridges were composed of two stacked rosettes. See figure 2 for the instrumentation layout.

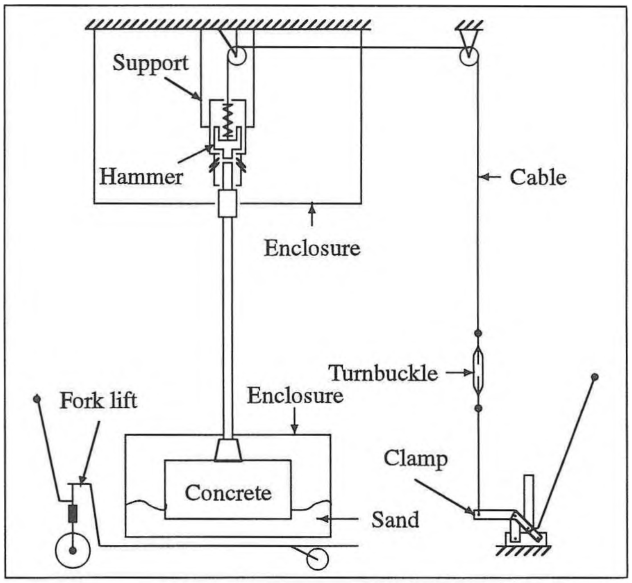

Figure 1: Test fixture schematic

The acoustic measurements were made with a circular antenna which can be positioned everywhere on the vertical axis. The antenna was equipped with eight microphones to adequately characterize the directional behaviour of the bending waves. The microphones were at 40 cm of the rod.

A Brüel & Kjær type 8309 impact accelerometer fixed on the hammer was used to quantify the impact force.

Two Sony multi-channel DAT recorders were used to store the measurements for future processing. The recorders allowed a 10 kHz bandwidth for 16 channels.

A strict procedure was adopted to take the measurements. Five impacts were recorded for each of the ten measurement stations. This important number of measurement points was needed because of the non-uniform sound field. After each impact, the drilled hole was cleaned and the rod was turned to present a new surface to the bit.

Signal processing and analysis were achieved using LabVIEW software running on a personal computer. Acoustic and vibration signals were windowed from the moment the hammer touched the rod to the moment the hammer fell back on it after the rebound. The windowed signals were about 100 ms long, enough for the signals to be damped out. The signals were zero padded to 4096 samples (171 ms) to increase the frequency resolution of spectrums. A Fourier transform was performed on each impact.

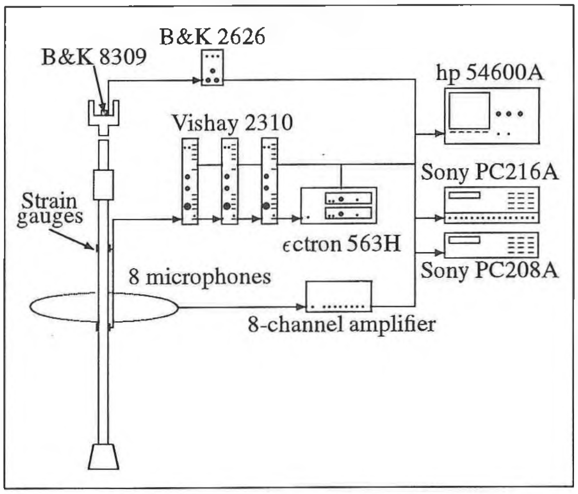

Figure 2: Measurement and recording instrumentation

3 Results

3.1 Test fixture versus percussion drill

In order to evaluate if the test fixture is representative of a percussion drill, vibroacoustic measurements were conducted on a running hydraulic drill. These measurements showed that between two successive impacts the amplitude dies out due to strong damping. Therefore, the one by one impact generation mechanism of the test fixture is not a significative limitation.

Figure 3 compares the axial stress measured on the test fixture and on a percussion drill. The same instrumented rod was used for both tests. The traces show many similarities but differ by peak stress amplitude and damping rate. The peak stress produced by the percussion drill is about twice the one produced by the test fixture. The piston velocity explains the difference. Although the peak stress was lower, the level is high enough to drill in a concrete block. On a drill in real operating conditions, the longitudinal vibrations amplitudes are more damped.

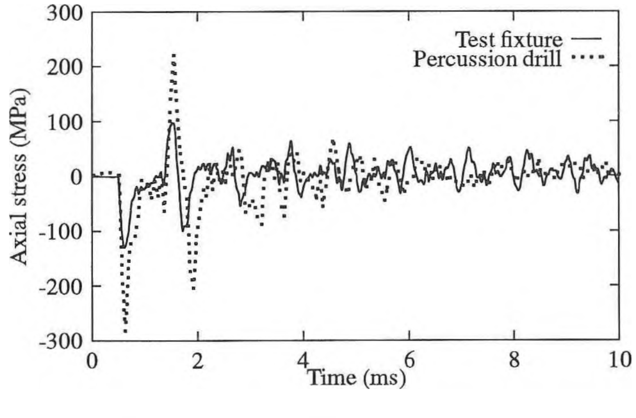

Figure 3: Axial stress time domain traces compared for the test fixture and a percussion drill

3.2 Noise radiation

Figure 4 shows the influence of the alignment of the rod with the hammer on the sound pressure levels. When the rod is aligned with the hammer, the axial modes sound radiation levels are comparable with those from flexural modes. Since spectral density is higher for flexural modes despite all the efforts to avoid the flexural modes excitation, the flexural modes still contribute more to the sound level than axial modes. When the rod is out of alignment by 2 degrees, flexural modes sound radiation gained up to 8 dBs. Vibration measurements showed that only the flexural vibrations were affected significantly when the alignment was changed.

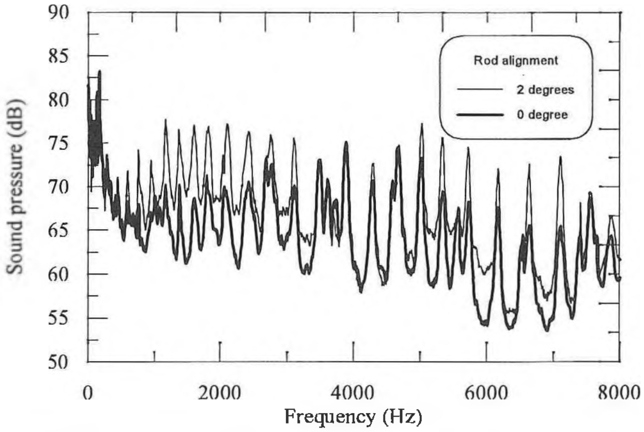

Figure 4: Comparison of sound levels for two rod alignments

Other measurements (not presented here) demonstrated that when the bit is not enclosed, the contribution of longitudinal modes to the sound radiation increased to a level at which the longitudinal modes become the dominant noise source. Sound pressure at frequencies corresponding to longitudinal modes increased by up to 15 dBs.

4 Conclusion

It is possible to reduce the drill rod noise of percussion drills by reducing only the flexural vibrations. However, the noise caused by axial vibrations will soon become dominant. Furthermore, we shall be concerned by the bit noise at the beginning of holes which is related to the axial vibrations.

The test fixture developed will be used to study potential solutions to the noise problem. The fixture was found to be adequate to simulate a percussion drill behaviour in many aspects.

5 Acknowledgement

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