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A STUDY OF AIR EXPULSION NOISE FROM A FORGING HAMMER

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INTRODUCTION

Air expulsion noise is the aerodynamic sound produced when air is forced from between the die surfaces of a forging hammer. Because of its short duration, air expulsion noise represents a minor part of the total noise generated by many impact forming machines. It is most significant during the finishing blows of the forging operation when die-to-die contact is made. However, it was established by Trengrouse (1974) and Brandt (1975) that the first negative peak in the sound pressure wave is caused by the air expulsion and, in some cases, the magnitude may be larger than the structural noise.

The purpose of this study was to search for methods of reducing the effect of air expulsion noise without enclosing the hammer operators. Some possible methods might be to locate the worker outside of the high intensity sound field or to modify the die configuration to reduce the air expulsion noise. This study is confined to die modifications that will reduce air expulsion noise levels.

The results have illustrated two modifications that may reduce air expulsion noise. The first method is based on the fact that the sound pressure and flow velocity generated by the round dies was less than one-half that generated by the square dies. This is a result of the spatial dissipation in a cylindrical wave that is absent in a plane wave. The second method of reducing air expulsion noise consists of increasing the rate of dissipation of the wave by artificially inducing turbulence at the die edge. This could be accomplished by serrations, screens or lips at the die edge. Boundary layer blowing at the die edge may also increase the turbulent dissipation.

Some of the more significant studies related to air expulsion noise are presented below. Holmes (1973) was the first investigator to study the air expulsion phenomenon. His work was concerned with aerodynamic impact sounds generated by foot-steps and included sound generated by suddenly accelerating surfaces. Trengrouse and Bannister (1974) were the first to isolate the air expulsion phenomena from structure-generated impact noise. They were also the first authors to attempt an analysis of air expulsion as a compressible flow problem. Brandt (1975) performed an extensive experimental analysis of air expulsion in which he measured both the sound pressure and flow velocity of the air expulsion wave. His work represents a quantum jump in knowledge of this phenomenon. Akay (1978) presents a comprehensive review of impact noise literature and describes the basic mechanisms of sound generation in the impact process. Malosh (1980) performed an extensive experimental and theoretical analysis of air expulsion noise. Much of the data presented in the study is drawn from that work.

EXPERIMENTAL WORK

The experimental work consisted of both field and laboratory measurements of air expulsion noise generated by a full size and model forge hammer. The hot-wire anemometer (HWA) and condenser microphone with sound level meter (SLM) were used to measure the velocity and pressure of the air expulsion wave. Laboratory studies with a shock tube show these instruments to be adequate in terms of high frequency response for measuring air expulsion noise. Sound pressure, flow velocity and ram position were the parameters measured in all of the tests. The output of these devices was displayed on an oscilloscope and photographed for permanent record. The field tests were performed on a 900 kg drop hammer with a maximum drop height of 86 cm. For these tests, 23 cm diameter flat dies were installed in the machine. The laboratory tests were performed on a model drop hammer made of wood and styrofoam designed to be as devoid of structure borne noise as possible. The maximum drop height of the ram was also 86 cm. Square or round flat faced dies of 23 cm could be installed in the machine.

Typical sound pressure and velocity time histories for the model drop hammer are shown in Figure 1. These traces were made at several locations from the edge of the round dies in the impact plane. They are correlated with the die contact event. The traces in this figure exemplify the three stages of behavior in the air expulsion process described by Malosh (1980). The first stage covers the gradual commencement of flow between the dies as the ram begins to move from rest. This is called the incompressible stage and appears to be a potential flow. The second stage occurs when the dies are relatively close together. This is the finite wave stage where high particle velocities and sound pressure levels occur. The third stage begins just before the dies make contact and includes all time after die contact. During this stage, the flow velocity field exhibits the behavior of an unsteady turbulent jet.

Figure one also shows a transition region 5 to 10 cm from the die edge where the first negative peak sound pressure is apparently amplified and reaches a maximum. At this point, the waves seem to interact and, at points farther from the die edge, the velocity wave dissipates very rapidly and the sound-pressure wave propagates as an acoustic wave. This region was observed around the full size hammer and model hammer with square dies. In that case, the transition region extended from 5 to 12cm. For the square dies, the peak sound pressure (-921 N/m^2) also occurred at 5.1cm from the die edge. However, at 10.2cm from the die edge, the sound pressure for the square dies was still -597 N/m^2 compared to -158 N/m^2 for the round dies. At 12.7cm from the die edge, the peak sound pressure for the square dies was still -149 N/m^2.

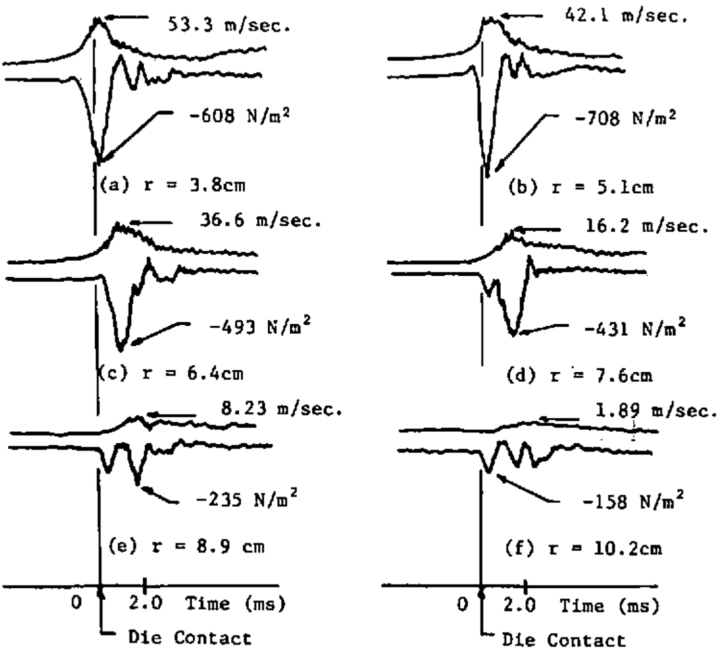

Figure 1. Simultaneous Flow Velocity (top trace) and sound pressure (bottom trace) in the impact plane at r cm distant from the edge of 23cm round dies, mounted in the model drop hammer.

This reduced spatial dissipation of the square dies which is also supported by the theoretical work of Malosh (1980), places the acoustic source farther from the die edge which therefore causes higher far field noise levels. The results show that noise levels for the round dies were as much as 10dB lower than the square dies.

TURBULENCE EFFECTS

Malosh (1980) showed that the air expulsion wave propagates as an unsteady turbulent jet much like the starting plume of a jet or the propagation of a perturbation in a turbulent jet. If indeed this is true then it may be possible to decrease the magnitude of the air expulsion wave in the far field by increasing the rate of turbulent decay. There are several modifications to the die edge such as a sharp-edge lip, fine notches, screens, vanes, or serrations that may accomplish this goal. Boundary layer blowing just inside the die edge may also increase turbulent decay of the jet.

The pressure wave amplification observed in figure 1 would also be influenced by the artificially induced turbulence. This amplification phenomenon is similar to the wave amplification Maestrello (1981) observed in an axisymmetric jet. It is his hypothesis that an acoustic sound within the potential flow cone of the jet excites instability waves that result in the pressure wave amplification. Destruction of the potential flow core by artificial methods such as a screen might eliminate this pressure wave amplification and further attenuate the air expulsion noise.

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